DOCUMENT RESUME

ED 408 176 SE 060 264

TITLE	Missouri's Framework for Curriculum Development in Science K-12.
INSTITUTION	Missouri State Dept. of Elementary and Secondary Education, Jefferson City.
PUB DATE	96
NOTE	233p.
AVAILABLE FROM	Missouri Department of Elementary and Secondary Education, P.O. Box 480, Jefferson City, MO 65102-0480.
PUB TYPE	Guides - Non-Classroom (055)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Biological Sciences; *Curriculum Development; Earth Science; Ecology; *Educational Resources; *Educational Strategies; Elementary Secondary Education; Inquiry; Integrated Curriculum; Physical Sciences; Relevance (Education); *Science Education; Scientific Concepts; Space Sciences
IDENTIFIERS	Missouri

ABSTRACT

Missouri's Framework for Curriculum Development in Science acknowledges that teachers will bring the vision, ideals, and principles of the Show-Me Standards of the state of Missouri into their classrooms in exciting and innovative ways. The role of the frameworks is to provide districts with a "frame" for building curricula using the standards as a foundation. The frameworks provide indicators of what students should know and be able to do in science by the end of grades 4, 8, and 12. They contain suggested resources, discussions on issues and current practices, and examples of quality student work. Many of the suggested activities encourage an integrated, interdisciplinary curriculum. The final section provides a discussion of how districts might begin to explore the advantages of curriculum integration. The major strands include: (1) Scientific Inquiry; (2) Scientific Relevance; (3) Matter and Energy; (4) Force, Motion, and Mechanical Energy; (5) Universe; (6) Earth systems; (7) Living Systems; and (8) Ecology. The section on suggested practices for teaching and learning science contains topics on assumptions, science teaching standards, and vignettes. The appendix includes samples of quality student work. Contains 16 references. (JRH)

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Framework for Curriculum Development in Science K-12

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Further Acknowledgments:

Missouri's Frameworks for Curriculum Development have been reviewed by over 200 district Professional Development Committees, members of professional organizations of the various disciplines, vocational and special education teachers, members of the State Board of Education, and board members of the Missouri School Boards Association and the Missouri Congress of PTA. Subsequently, many of the suggestions offered by these reviewers have been incorporated into the Frameworks.

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PREFACE

In recent years, people from all walks of American life have participated in wide-ranging discussions about the direction of American education. While the situation is not as dire as some critics would have us believe, there is clearly a need for the review of current school organization, curricula, teaching practices and academic standards for students. As a result of these discussions, many legislators, educators, parents, and business leaders across the nation have initiated projects designed to develop high academic standards in safe learning environments for all students. The Show-Me State is no exception.

A Vision for Missouri Schools

In charting a path for the future of Missouri public schools, a common vision of what that future looks like is an essential first step. These schools must be physically and intellectually safe places for students. In these schools we believe all students are capable of learning and are challenged by high expectations. To meet this challenge, students must have a solid foundation of basic knowledge and skills. In addition, they must also be able to apply what they know.

To support the development of such students, teachers actively engage them in exploring, analyzing and understanding the world. Learning is interesting, hands-on and has real applications that are important to students. We recognize that students learn better, remember more, and develop deeper understandings of both knowledge and thinking processes if they have the opportunity to actively explore content and concepts. They view learning as the on-going process of extending and fine tuning their ideas and understanding through application. As a result, they take responsibility for their own learning, see its worth and make connections to the world beyond the classroom.

In addition, teachers and administrators in these communities see themselves as learners. They gain greater insight into their profession from their experiences among their students and in contact with their colleagues. They constantly seek to extend their knowledge and expertise, and frequently engage in professional development activities to deepen their professional skills and understanding.

The schools we envision also involve parents, business leaders and interested citizens in a multitude of educational activities. In turn, these people accept the responsibility for supporting and nurturing the learners within the school and see themselves as an important part of the learning community.

The Outstanding Schools Act

The passage of the Outstanding Schools Act in 1993 signaled Missouri's commitment to a public school system that purposefully prepares young people for the 21st century and assures our state's continued economic vitality. The Show-Me State has issued an ambitious, common-sense agenda by setting challenging academic standards for all students, by supporting professional development of educators to improve the quality of curriculum and instruction, and by providing more equitable funding for public education. In addition, the Outstanding Schools Act calls for increased accountability in improving student academic performance for all of Missouri's public school districts and school buildings. In summary, it addresses the following initiatives:

The Show-Me Standards–a set of 73 rigorous standards–intended to define what students should know and be able to do by the time they graduate from Missouri's public high schools;

Curriculum Frameworks–frameworks for curriculum development in communication arts, fine arts, health and physical education, mathematics, science, social studies and curriculum integration–intended to provide assistance to districts in aligning local curriculum with the Show-Me Standards;

A New Statewide Assessment–a new assessment system of performance events and multiple choice and short answer questions–intended to provide an indication of how well students are meeting the Show-Me Standards and how well they compare academically with other students across the nation;

Professional Development for Educators–one percent of the local district's basic state aid and one percent of the state educational budget to be set aside to support professional development–intended to improve student performance through improving the performance of educators; and

Professional Standards for New Educators–professional standards defining what graduating pre-service teachers should know and be able to do as certificated Missouri teachers–intended to ensure that there is a strong link between teacher preparation and the expectations of the school community.

Strategies for Including All Students

We believe virtually all students are able to learn, even though all students are not succeeding in school. Many of them fall behind and leave school before graduation. These strategies help all students become more engaged in learning:

- Use a multisensory approach to teaching and learning, including auditory, visual and hands-on techniques
- Present concepts in several ways, linking them to what students already know and checking frequently for understanding
- Model learning strategies and encourage students to talk about their own thinking and learning processes
- Teach students how to organize their thoughts using drawings, charts, outlines, thumbnail sketches, and computer generated flowcharts, spread sheets, and databases, etc.
- Encourage students to use technology as a user-friendly tool for learning
- Use questions and approaches that require inquiry, problem solving and the synthesizing of ideas
- Provide equal opportunities for all students to participate in class activities
- Adapt materials to accommodate students with special needs
- Provide real-life and work applications of what students should know and be able to do
- Develop a classroom assessment program that allows all students to show what they know and can do

Technology in Missouri Education

The Outstanding Schools Act also provides funding through technology grants for districts to obtain and access the latest technologies. The Show-Me Standards emphasize understanding and use of technology as a tool for learning, and *Missouri's Frameworks for Curriculum Development* suggest many ways to incorporate the use of technology in the classroom. Because students learn and demonstrate knowledge in a variety of ways, technologies can help teachers accommodate the learning and presentation styles of each student, keep students on task, provide individualized assistance and support students who must be absent from class.

Technology also plays a major role in adequately preparing students for continuous learning and for the workplace. More households are becoming dependent on technology (such as subscribing to on-line banking and informational services and operating computers, VCRs, CD-ROMs and voice mail). Growing numbers of jobs require an understanding or use of technology. In fact, we cannot imagine the impact technology will have on the lives of our children and grandchildren.

An important outgrowth of technology in our schools is that it may also enhance the local economy by encouraging schools and communities to share technologies and training. Through the Outstanding Schools Act, our students and other community members will have opportunities to become technologically literate.

The Missouri School Improvement Program

The Missouri School Improvement Program (MSIP) provides additional support to these measures by requiring districts to have a long-range plan for ongoing curriculum development and revision, to develop written curriculum guides for all curricular areas, and to implement the stated curriculum. In the second cycle of reviews (1996-2001), MSIP teams will evaluate whether a district's written curriculum addresses the Show-Me Standards. Curriculum guides for at least one content area must be revised to reflect the Show-Me Standards one year after the adoption of *Missouri's Frameworks for Curriculum Development* by the State Board of Education. Guides for the six content areas contained in the frameworks must be revised to address the Show-Me Standards by the start of the 2000-2001 school year. In planning for curriculum development and revision, districts may wish to consider the Department's schedule for implementation of the new assessment system:

Mathematics	Spring 1997
Communication Arts	Spring 1998
Science	Spring 1998
Social Studies	Spring 1999
Health/Physical Education	Spring 2000
Fine Arts	Spring 2000

The first administrations of the mathematics, communication arts, and science assessments will be voluntary. Districts will be required to administer the new mathematics assessment in 1998 and the new communication arts and science assessments in 1999. At the time each test is required, the *Missouri Mastery and Achievement Test* (MMAT) will no longer be used to collect

state achievement data. The remaining subject areas will be required as noted in the above list. Important curricular areas not included in the state assessment, such as foreign languages and practical arts, will find that the Show-Me Standards encompass knowledge and skills that are applicable for their students as well. In fact, the Show-Me Standards should be integrated throughout the entire K-12 curriculum so that all high school graduates will be better prepared to meet the challenges of the 21st century.

The Show-Me Standards

The Outstanding Schools Act requires that the State Board of Education oversee the development of "not more than 75 academic performance standards." The Show-Me Standards, developed over a period of two years with input from teachers, school officials and citizens, are the result of this mandate. There are **40 *knowledge (content) standards*** that provide a solid foundation of knowledge in communication arts, fine arts, health and physical education, mathematics, science, and social studies.

Business and higher education communities have pointed out that, in general, students are graduating with some factual knowledge, but they are not skilled in abstract thinking, problem solving, and working cooperatively or collaboratively. Students need practice in integrating, applying and transferring what they are learning in one context or content area to new and different situations. To remedy this, the Missouri teachers who developed the Show-Me Standards proposed **33 *performance (process) standards*** . These standards include important process skills that students should master in order to successfully gather, analyze and apply information and ideas; communicate effectively within and beyond the classroom; recognize and solve problems; and make decisions and act as responsible members of society. (The Show-Me Standards follow this Preface.)

While intended to establish higher expectations for **all** of Missouri's students, the 73 Show-Me Standards do not represent everything a student should or will learn. Graduates who meet these standards, however, should be well-prepared for further education, work, and civic responsibilities.

The Department of Elementary and Secondary Education believes that the preservation of local control is a hallmark of the Outstanding Schools Act. Local school districts have the authority, the ability and the resources to develop rigorous and challenging curriculum that will prepare their students to be successful in the 21st century. The Department's role is to support districts in this endeavor, helping them carry out this task by offering technical assistance, professional development opportunities, and new technologies. Each school district must determine how its curriculum will be structured and which methods to use to implement that curriculum in the classroom. We believe that local educators, parents, employers, and community leaders know best how to incorporate the Show-Me Standards into their districts' curricula to meet the needs of their students.

Missouri's Frameworks for Curriculum Development

Missouri's Frameworks for Curriculum Development in communication arts, fine arts, health and physical education, mathematics, science, social studies, and curriculum integration acknowledge that teachers will bring the vision, ideals and principles of the Show-Me Standards into their classrooms in exciting and innovative ways. The role of the frameworks is to provide districts with a "frame" for building curricula using the Show-Me Standards as a foundation. District curriculum guides furnish the interior curriculum plan and appropriate instruction. District guides probably are not organized in the same way as the six content frameworks. The good news is that they do not have to be. In fact, although the frameworks use a three-column format ("What All Students Should Know," "What All Students Should Be Able to Do," and "Sample Learning Activities"), the committees who wrote the frameworks approached their task in ways that best appeared to fit their particular content areas. For example, the social studies framework is organized around important questions; communication arts, around the four goals of the Show-Me Standards; and science, around the knowledge standards. Each group of framework writers had valid reasons for their organizational plan, just as curriculum developers in each district will and should. Similarly, local curriculum guides should be in a format that is the most useful for the district's teachers.

Curriculum Frameworks Are Resources–

- To assist districts in developing curriculum consistent with the Show-Me Standards
- To indicate what students should know and be able to do by the end of grades 4, 8 and 12.
- To support teachers in providing high-quality learning experiences for **all** students
- To suggest examples of hands-on, real-world activities and classroom performance assessments
- To suggest effective learning and teaching strategies supported by research and practice
- To initiate discussions concerning curriculum integration within and across classrooms
- To provide examples of quality student work requiring knowledge and application of that knowledge

Curriculum Frameworks Are Not–

- Not required by law for district use
- Not detailed lesson plans or curricula
- Not items on which all students must be tested
- Not directives for uniform programs or textbook adoption
- Not mandates for inclusion of specific teaching methods or programs
- Not a format that all district curriculum guides must follow

As the writers worked on developing the frameworks, they asked themselves questions that are very similar to what local curriculum developers must ask: How do we see the Show-Me Standards playing out in this content area and across the curriculum? Are there important areas addressed by the standards that are not included in our current curriculum and how should we address these? Are we presenting a balanced curriculum, K-12? Are we giving students opportunities to apply in real situations the knowledge they have learned? How will the emphasis on what students know and are able to do change instruction, or will it? Do our assessments model and support the taught curriculum? In essence, the framework writers have tried to make the work of local curriculum committees easier by establishing a relationship between the Show-Me Standards and the K-12 curriculum in the six content areas. For some districts this step is unnecessary; for others, it will help give much needed direction.

In addition, the frameworks provide indicators of what students should know and be able to do by the end of grades 4, 8 and 12. They contain suggested resources, discussions of issues and current practices, and examples of quality student work. Many of the suggested activities encourage an integrated, interdisciplinary curriculum. In fact, the final section of *Missouri's Frameworks for Curriculum Development* provides a discussion of how districts might begin to explore the advantages of curriculum integration.

Meeting the Challenge

We know that, in most cases, the level of expectation and the interest of the students determine the level of performance. When schools set high standards and provide access to meaningful curriculum for every learner, students and teachers flourish. Success for all students is not a dream but a reality.

With the advent of the 21st century, we are on the threshold of more life-changing events than we can ever imagine. Computers and technology are making our lives both more productive and more complex. The Internet, fax machines, fiber-optic networks, and voice mail are changing the ways we communicate and do business. Information on every topic is readily available at the push of a button. Two bread-winners per family are the norm rather than the exception. Workers can no longer select a particular career and expect to do the same job in the same way year after year. As citizens, we must be prepared to make important decisions which will affect the lives of future generations in positive ways. The challenge we face now is how to educate our children to be successful as individuals and as members of society in a world that most of their grandparents would not even recognize. Working together, we can do it. What an exciting time to be involved in the education of Missouri's students!

THE SHOW-ME STANDARDS

Authority for the Show-Me Standards: Section 160.514, Revised Statutes of Missouri, and the Code of State Regulations, 5 CSR 50-375.100

PERFORMANCE (PROCESS) STANDARDS

GOAL 1: Students in Missouri public schools will acquire the knowledge and skills to gather, analyze and apply information and ideas.

Students will demonstrate within and integrate across all content areas the ability to

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.3 design and conduct field and laboratory investigations to study nature and society
1.4 use technological tools and other resources to locate, select and organize information
1.5 comprehend and evaluate written, visual and oral presentations and works
1.6 discover and evaluate patterns and relationships in information, ideas and structures
1.7 evaluate the accuracy of information and the reliability of its sources
1.8 organize data, information and ideas into useful forms (including charts, graphs, outlines) for analysis or presentation
1.9 identify, analyze and compare the institutions, traditions and art forms of past and present societies
1.10 apply acquired information, ideas and skills to different contexts as students, workers, citizens and consumers

GOAL 2: Students in Missouri public schools will acquire the knowledge and skills to communicate effectively within and beyond the classroom.

Students will demonstrate within and integrate across all content areas the ability to

2.1 plan and make written, oral and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.3 exchange information, questions and ideas while recognizing the perspectives of others
2.4 present perceptions and ideas regarding works of the arts, humanities and sciences
2.5 perform or produce works in the fine and practical arts
2.6 apply communication techniques to the job search and to the workplace
2.7 use technological tools to exchange information and ideas

GOAL 3: Students in Missouri public schools will acquire the knowledge and skills to recognize and solve problems.

Students will demonstrate within and integrate across all content areas the ability to

3.1 identify problems and define their scope and elements
3.2 develop and apply strategies based on ways others have prevented or solved problems
3.3 develop and apply strategies based on one's own experience in preventing or solving problems
3.4 evaluate the processes used in recognizing and solving problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.6 examine problems and proposed solutions from multiple perspectives
3.7 evaluate the extent to which a strategy addresses the problem
3.8 assess costs, benefits and other consequences of proposed solutions

GOAL 4: Students in Missouri public schools will acquire the knowledge and skills to make decisions and act as responsible members of society.

Students will demonstrate within and integrate across all content areas the ability to

4.1 explain reasoning and identify information used to support decisions
4.2 understand and apply the rights and responsibilities of citizenship in Missouri and the United States
4.3 analyze the duties and responsibilities of individuals in societies
4.4 recognize and practice honesty and integrity in academic work and in the workplace
4.5 develop, monitor and revise plans of action to meet deadlines and accomplish goals
4.6 identify tasks that require a coordinated effort and work with others to complete those tasks
4.7 identify and apply practices that preserve and enhance the safety and health of self and others
4.8 explore, prepare for and seek educational and job opportunities

KNOWLEDGE (CONTENT) STANDARDS

Communication Arts

In Communication Arts, students in Missouri public schools will acquire a solid foundation that includes knowledge of and proficiency in

CA 1 speaking and writing standard English (including grammar, usage, punctuation, spelling, capitalization)
CA 2 reading and evaluating fiction, poetry and drama
CA 3 reading and evaluating nonfiction works and material (such as biographies, newspapers, technical manuals)
CA 4 writing formally (such as reports, narratives, essays) and informally (such as outlines, notes)
CA 5 comprehending and evaluating the content and artistic aspects of oral and visual presentations (such as storytelling, debates, lectures, multimedia productions)
CA 6 participating in formal and informal presentations and discussions of issues and ideas
CA 7 identifying and evaluating relationships between language and culture

Fine Arts

In Fine Arts, students in Missouri public schools will acquire a solid foundation that includes knowledge of

FA 1 process and techniques for the production, exhibition or performance of one or more of the visual or performed arts
FA 2 the principles and elements of different art forms
FA 3 the vocabulary to explain perceptions about and evaluations of works in dance, music, theater and visual arts
FA 4 interrelationships of visual and performing arts and the relationships of the arts to other disciplines
FA 5 visual and performing arts in historical and cultural contexts

Health/Physical Education

In Health/Physical Education, students in Missouri public schools will acquire a solid foundation that includes knowledge of

HP 1 structures of, functions of, and relationships among human body systems
HP 2 principles and practices of physical and mental health (such as personal health habits, nutrition, stress management)
HP 3 diseases and methods for prevention, treatment and control
HP 4 principles of movement and physical fitness
HP 5 methods used to assess health, reduce risk factors, and avoid high risk behaviors (such as violence, tobacco, alcohol and other drug use)
HP 6 consumer health issues (such as the effects of mass media and technologies on safety and health)
HP 7 responses to emergency situations

Mathematics

In Mathematics, students in Missouri public schools will acquire a solid foundation that includes knowledge of

MA 1 addition, subtraction, multiplication and division; other number sense, including numeration and estimation; and the application of these operations and concepts in the workplace and other situations
MA 2 geometric and spatial sense involving measurement (including length, area, volume), trigonometry, and similarity and transformations of shapes
MA 3 data analysis, probability and statistics
MA 4 patterns and relationships within and among functions and algebraic, geometric and trigonometric concepts
MA 5 mathematical systems (including real numbers, whole numbers, integers, fractions), geometry, and number theory (including primes, factors, multiples)
MA 6 discrete mathematics (such as graph theory, counting techniques, matrices)

Science

In Science, students in Missouri public schools will acquire a solid foundation that includes knowledge of

SC 1 properties and principles of matter and energy
SC 2 properties and principles of force and motion
SC 3 characteristics and interactions of living organisms
SC 4 changes in ecosystems and interactions of organisms with their environments
SC 5 processes (such as plate movement, water cycle, airflow), and interactions of Earth's biosphere, atmosphere, lithosphere, and hydrosphere
SC 6 composition and structure of the universe and the motions of the objects within it
SC 7 processes of scientific inquiry (such as formulating and testing hypotheses)
SC 8 impact of science, technology, and human activity on resources and the environment

Social Studies

In Social Studies, students in Missouri public schools will acquire a solid foundation that includes knowledge of

SS 1 principles expressed in the documents shaping constitutional democracy in the United States
SS 2 continuity and change in the history of Missouri, the United States and the world
SS 3 principles and processes of governance systems
SS 4 economic concepts (including productivity and the market system) and principles (including the laws of supply and demand)
SS 5 the major elements of geographical study and analysis (such as location, place, movement, regions) and their relationships to changes in society and environment
SS 6 relationships of the individual and groups to institutions and cultural traditions
SS 7 the use of tools of social science inquiry (such as surveys, statistics, maps, documents)

OVERVIEW OF SCIENCE EDUCATION

RATIONALE FOR THE STUDY OF SCIENCE

The central purpose and primary task of science education in Missouri are to awaken in students at all levels a sense of joy and wonder, in the excitement and intellectual power of science. Science education should develop an understanding of the natural and physical worlds in which we live, the relationships among the phenomena of those worlds, the effects of those worlds on human living and should explain how human living affects the natural and physical worlds, and how knowledge of these worlds is discovered by those who study science.

As we move into the 21st century, science and technology will play an increasingly important role in all aspects of our society. It is imperative, therefore, that our future decision makers develop positive attitudes about and confidence in their ability to solve problems using scientific concepts and principles. These attitudes foster curiosity to understand and appreciate the natural world as well as to comprehend the impact of science and technology on the individual, culture, and society. The quality of life in the future will rest on the contributions of the students in schools now. With this in mind, the Missouri Science Curriculum Framework was designed to promote high expectations for all students, teachers, and districts and to encourage the development and adoption of curricula that provide the opportunity for all students to learn the skills, attitudes, and knowledge important for scientific literacy.

Scientifically literate individuals:

1. are aware that science, mathematics, and technology are interdependent, each with strengths and limitations;
2. understand and use key concepts, principles, and laws of science;
3. recognize the phenomena of the natural world as well as its diversity and unity;
4. and use scientific knowledge and scientific ways of thinking for individual and social purposes.

Missouri students should come to understand that science is an intellectual and social endeavor, a means by which we gain understanding and control over real-world situations, as well as part of our effort to survive and flourish. Science processes are used to gather information, create and evaluate hypotheses, pose theories for understanding the universe in which we live, and communicate these theories to others.

KEY PRINCIPLES

Schools are entrusted with the task of helping students acquire the complex, interconnected knowledge that will enable them to participate in the community of scientifically literate people and to engage in the activities that scientific knowledge makes possible. To fulfill this role as they develop their science curricula, Missouri schools will need to consider the following key principles:

1. **All students will have the opportunity to attain high levels of scientific literacy and learn the rigorous content required.**

This principle implies that all students will have the opportunity to learn science and that students can achieve high levels of understanding and skill in science. No one can discover an aptitude or a gift for science without having an opportunity to experience it. The knowledge and skills described in this framework can be achieved by all students. Undoubtedly, some students will achieve this knowledge sooner than others and at different depths of understand ing. Decisions about programs and the means to accommodate the different rates of learning are left to curriculum developers, local school administrators, and science teachers.

2. **All students will develop rigorous knowledge and understanding of science so they can use that knowledge in relationship to scientific, social, personal, and historical perspectives.**

Understanding science implies the acquisition of basic facts, laws, principles, and vocabulary needed to describe events and objects, ask questions, construct explanations of natural phenom ena, test those explanations in different ways, and communicate ideas to others. This principle encourages the shift of curriculum and instructional emphasis from topics that rely exclusively on information (e.g., knowing the parts of a cell) to topics that generate understanding (e.g., knowing the parts of a cell, what they do, how they are related, and what affects them). The various topics in science must be introduced as an integrated whole, revealing the interdepen dence of all strands of science. In addition, the interdependence of science and other disciplines must be continually stressed. Activities must be designed to encourage students to recognize the essential need to use skills and knowledge from all disciplines in the process of scientific inquiry.

3. **For all students to understand more science, more resources (i.e., time, personnel, and materials) will be devoted to science education.**

If students are to understand the "big ideas" of science, fundamental knowledge of concepts and processes, and investigations using this knowledge must be emphasized. To accomplish this, science education must receive equal emphasis with other content areas throughout pri- mary, intermediate, middle, and secondary levels, while being applied with increasing complex ity as students mature and progress. Schools need to provide time to teach science, develop well-prepared teachers, and supply adequate materials (books, equipment, space, etc.).

4. **Science learning will have an active focus.**

Learning science involves physical and mental activity that implies that activities are "hands- on" as well as "minds-on." Science teaching must involve students in inquiry-based investiga- tions, connect what they now know and what they learn from other sources, and apply what they learn to new situations. This principle implies shifting the emphasis from teachers as a "sage on the stage" (presenting information and covering topics) to teachers as facilitators (guiding the students to learn science through active involvement).

The ***National Science Education Standards*** envision change throughout the educational system encompassing the following shifts in emphases (reprinted with permission):

CHANGING EMPHASES IN SCIENCE EDUCATION

Less emphasis on:	More emphasis on:
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, Earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

CHANGING EMPHASES TO PROMOTE INQUIRY

Less emphasis on:	More emphasis on:
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Emphasis on individual process skills such as observation or inference	Using multiple process skills—manipulation, cognitive, procedural
Getting an answer	Using evidence and strategies for developing or revising an explanation
Science as exploration and experiment	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusions	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of student ideas and conclusions to teacher	Public communication of student ideas and work to classmates

PURPOSE OF THIS FRAMEWORK

The science curriculum set forth in this document provides directions for an innovative approach to science education in Missouri, as well as a philosophical foundation for comprehensive science education programs. It provides suggestions about what to teach and examples of how to teach and how to assess student learning. The Missouri Department of Elementary and Secondary Education will seek to support school districts as they address these problems through professional development programs, the science component of the Missouri Assessment Program, and the development of models of teaching and learning strategies.

The science framework encourages the development and adoption of curricula based on current research on how students learn. It encourages reform based on hands-on experimentation and learner-generated questions, investigations, hypotheses, and models. Whenever possible, lessons should use raw data and primary sources, along with manipulative, interactive, and physical materials. Students should be allowed to explore and discover, both individually and in groups, in a manner that encourages them to engage in dialogue, both with the teacher and with each other. Lessons should engage and challenge students as active learners responsible for their own knowledge and be driven by student thinking. Instructional strategies and/or content should be altered based on student responses and be culturally relevant.

The science framework is designed to facilitate long-term, statewide science education reform, leading to an appreciation of lifelong scientific learning, an in-depth understanding of science concepts, an appreciation of the impact of science on society, and the acquisition of problem-solving skills that will prepare students for the year 2000 and beyond. The document provides direction, a philosophical foundation, and a curricular framework from which educators may construct comprehensive science education programs. It is not a comprehensive document, however, and should be used in conjunction with other science education reform documents such as the National Science Education Standards and Project 2061's Benchmarks for Scientific Literacy.

PHILOSOPHY OF PROGRESSION

The following is a philosophy of the progression of science education for the developmental levels addressed in the frameworks:

Primary Level (K-2)

From their very first day in school, students should be actively engaged in learning to view the world scientifically. That means encouraging them to ask questions and to seek answers, collect things, count and measure things, make qualitative observations, organize collections and observations, discuss findings, etc. Getting into the spirit of science and enjoying science are what count most.

Intermediate Level (3-4)

As children continue to investigate the world, the consistency premise can be strengthened by putting more emphasis on how they hypothesize the inconsistency of results of investigations.

When students observe differences in the way things behave or get different results in repeated investigations, they should identify what differs from trial to trial. The point is that different or inconsistent findings can lead to interesting new questions to be investigated. This emphasis on scientific engagement calls for "hands-on, minds-on" activities.

Middle Level (5-8)

Middle school science should contribute to the development of scientifically literate persons and not simply prepare students for the next science course. Science should relate to students' personal lives, and enable them to begin examining societal issues having scientific and technological bases. Students should have many opportunities to approach problems in a concrete, hands-on manner. They should be encouraged to express their ideas with abstract symbols and explanations and to reflect on the science in which they are engaged. Student-directed discussions should afford opportunities to revise prior knowledge bases and to accept new realities based on new understandings of scientific knowledge.

Students will become more systematic and sophisticated in conducting investigations, some of which may last for weeks or more. They will develop a better understanding of what constitutes a good experiment. Efforts should be made to learn to control specific variables. Student investigations should make up a significant part of the total science experience. Student investigations should be accompanied by systematic learning of science concepts presented in a variety of ways.

High School Level (9-12)

Aspects of the scientific world view can be illustrated both studying historical episodes in science and by reflecting on developments in current science. Students should learn that theories based on valid evidence and logical arguments compete for acceptance and that acceptance is based on agreed-upon canons of research. Students' ability to understand abstract ideas increases at this level and they may comprehend the uncertain and tentative nature of science. Significant effort should be made to study the importance of statistical uncertainty and prediction in science.

Additional focus should be placed on providing opportunities to become aware of the great range of scientific areas that exist, as well as the intricate ways that these areas interact. This will lead to a more realistic view of how the world works and an appreciation for the wide variety of different career possibilities in science.

MAJOR ORGANIZING STRANDS

The best information available from current documents went into developing the core content of Missouri's science framework. Science for All Americans (AAAS), Benchmarks for Science Literacy (AAAS), the Content Core (NSTA), and the November 1994, draft of the National Science Education Standards were used to keep the Missouri science frameworks in line with the national trends. Many state frameworks from around the nation were also reviewed. Curriculum developers should understand this Framework is not an all-inclusive document for science curriculum planning.

The science core content is organized into the following eight strands with corresponding defining elements:

I. Scientific Inquiry
- A. Processes
- B. Investigations

II. Scientific Relevance
- A. Nature of Technology
- B. Historical Perspective
- C. Science as a Human Endeavor

III. Matter and Energy
- A. Properties, Characteristics and Structure of Matter
- B. Characteristics, Forms and Sources of Energy
- C. Interactions of Matter and Energy

IV. Force, Motion and Mechanical Energy
- A. Relative Motion
- B. Types and Properties of Forces and Motion
- C. Interactions of Forces and Motion

V. The Universe
- A. Characteristics of the Universe
- B. Motion of the Universe
- C. Tools of Space Exploration

VI. Earth Systems
- A. Physical Systems
- B. Processes of Systems

VII. Living Systems
- A. Structure/Function/Characteristics of Living Organisms
- B. Life Processes
- C. Diversity/interdependence
- D. Reproduction/Heredity
- E. Adaptation/Evolution

VIII. Ecology
- A. Interactions of Ecosystems
- B. Changes in Ecosystems

These strands serve as organizers for the content that provides the foundations for understanding and applying scientific knowledge and were chosen because the concepts could be easily categorized, are user-friendly to curriculum writers, and readily lend themselves to interdisciplinary connections. They emphasize the use of knowledge by providing examples that are linked to Missouri's Show-Me Standards. Content is introduced at the lower grade levels, then reinforced and extended in a spiraling manner at successively higher levels of understanding. Scientific Inquiry and Scientific Relevance are strands that can be incorporated in all the other strands.

OTHER ORGANIZERS

There are some very powerful ideas and ways of thinking important to science that cannot be assigned to any particular strand because they are woven throughout all of them. These approaches have been used throughout history to help observe, investigate, and understand the world around us. Such ideas and ways of thinking can be categorized into main themes, such as systems, models, constancy and change, and scale. Themes that are common to all areas of science can facilitate the teaching of integrated science. Although these themes are not used in this Framework as organizing topics as some textbooks have done, or as separate strands, educators are encouraged to incorporate these themes into their science curricula. These themes also facilitate interdisciplinary ties because they are approaches that are relevant to business, education, law and government, and other topics.

Systems

The main goal of teaching students about systems is that they will be better able to understand more complex systems by thinking about individual parts. This applies whether they are thinking about a car, a cell, an ecosystem, or a planet. Students should be encouraged to think of the properties of systems as resulting from interaction of the parts, rather than belonging to the parts. A complex system may have properties that are more than just a sum of parts. Systems can include processes as well as things. All systems are connected, contain subsystems and are themselves subsystems of larger systems. Feedback controls a system, in that the output from one part of the system (which can include material, energy, or information) can become the input for other parts. As students reach higher levels of understanding, they should be able to analyze systems, specifying their boundaries and subsystems, their relations to other systems, and identify inputs and outputs and how they interact as feedback.

Models

Physical, mathematical, and conceptual models are tools for learning about things or processes they were meant to resemble. Students should be exposed to the use of models that are progressively more abstract, starting with physical models in the lower grades, and various forms of conceptual and mathematical models later. Models (including computer models) are used to study processes that happen very slowly (such as erosion or ocean currents), or are dangerous (car crashes, drugs, nuclear winter). Students should understand, however, that models can never be exactly the same as what they are modeling, and their usefulness may be limited if they are too simple or too complex. The usefulness of models can be tested by comparing their predictions to actual measurements or observations in the real world.

Constancy and Patterns of Change

Constancy and change are subjects of intense study in almost all areas of science and mathematics. The nature and rate of change in all types of systems is of interest. Likewise, the lack of change, or constancy, is also a topic of intense study in all science disciplines. Students should develop understanding of this concept starting with the idea that things change in some ways (size, weight, color, and movement) and stay the same in some ways. Some changes take place so rapidly or slowly that they are hard to see; careful measurement must be done to understand them. Later students can measure, graph, and analyze change, and they can begin to study patterns of change (such as cycles in nature), and identify the feedback mechanisms of the cycles. Eventually they can understand that most systems are so complex, at the atomic scale as well as larger parts, that tiny differences in conditions result in unpredictable outcomes. Students can be introduced to constancy and change by observing aspects of themselves or their surroundings. As students build on these experiences, they can relate their understanding to constancy and change in physical, biological, and technological systems.

Scale

An understanding of scale is important since most measurable variables, such as mass, size, and time, show immense variations in nature. Students should learn to measure and observe more and more extreme values as they progress through school. This will build a knowledge base that will help them to understand an even more important aspect of scale– that the way in which things work often changes with scale. The most commonly examined example of this is the relationship of surface area to volume. As something changes size, its volume changes out of proportion to its surface area. The range of numbers that students can grasp increases with age, so that older students can develop their sense of scale by studying the immense size of the cosmos, the minute size of the atoms, and the enormous age of the Earth.

ORGANIZATIONAL "ROAD MAP"

Number of Strand

Name of Strand

SCIENCE K-12

Knowledge (Content) Standard

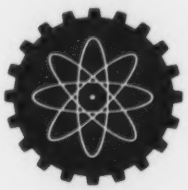
I. SCIENTIFIC INQUIRY

(SHOW-ME STANDARDS, SCIENCE 7)

Defining Elements

A. Processes of Scientific Inquiry

B. Investigations



K-12 Content Overview:

Scientific inquiry refers to the skills, habits of mind, and attitudes that promote lifelong scientific learning and the ability to apply scientific processes in all facets of life. Traditional approaches to teaching students scientific inquiry often do not give students an accurate perception of the true nature of the processes involved. The result is that many people have the impression that science is nothing more than "doing experiments," and following a rigid sequence of steps referred to as "the scientific method." In reality, the process is far from rigid. More imagination and inventiveness are involved in scientific inquiry than many people realize.

The best way for students to appreciate the true nature of scientific inquiry is for them to participate in scientific investigations based on real-life questions that progressively approximate good science. This approach, however, will require major changes in typical school laboratory activities. Traditional laboratory activities are very unlike real science. They are often teacher-initiated, with the teacher not only specifying the question to be investigated, but also the experimental design, the data to be collected, and ways of organizing and interpreting the data. If students are to understand the process of science, they must make these decisions themselves. Time must be made for revision and repetition of experiments, for presentations of results to other investigators, and even for response to criticism.

Science requires the use of mathematical skills and formulas. Mathematics and science programs should be coordinated so each enhance sthe learning of the other. By using data from actual science investigations, students will gain experience in dealing with the inconsistencies and errors that occur. Scientific explanations are often clarified through accurate measurements. The metric system should be used consistently throughout the K-12 science experience with emphasis on using the metric system and not the conversion between the metric and other systems.

In addition to in-class laboratory activities that approximate good science, it is important to introduce student investigations. These investigations should become more sophisticated so that before graduating from high school, students should cconduct at least one major investigation. Such investigations, whether individual or group, might take weeks or months to conduct, and may take place in or out of school.

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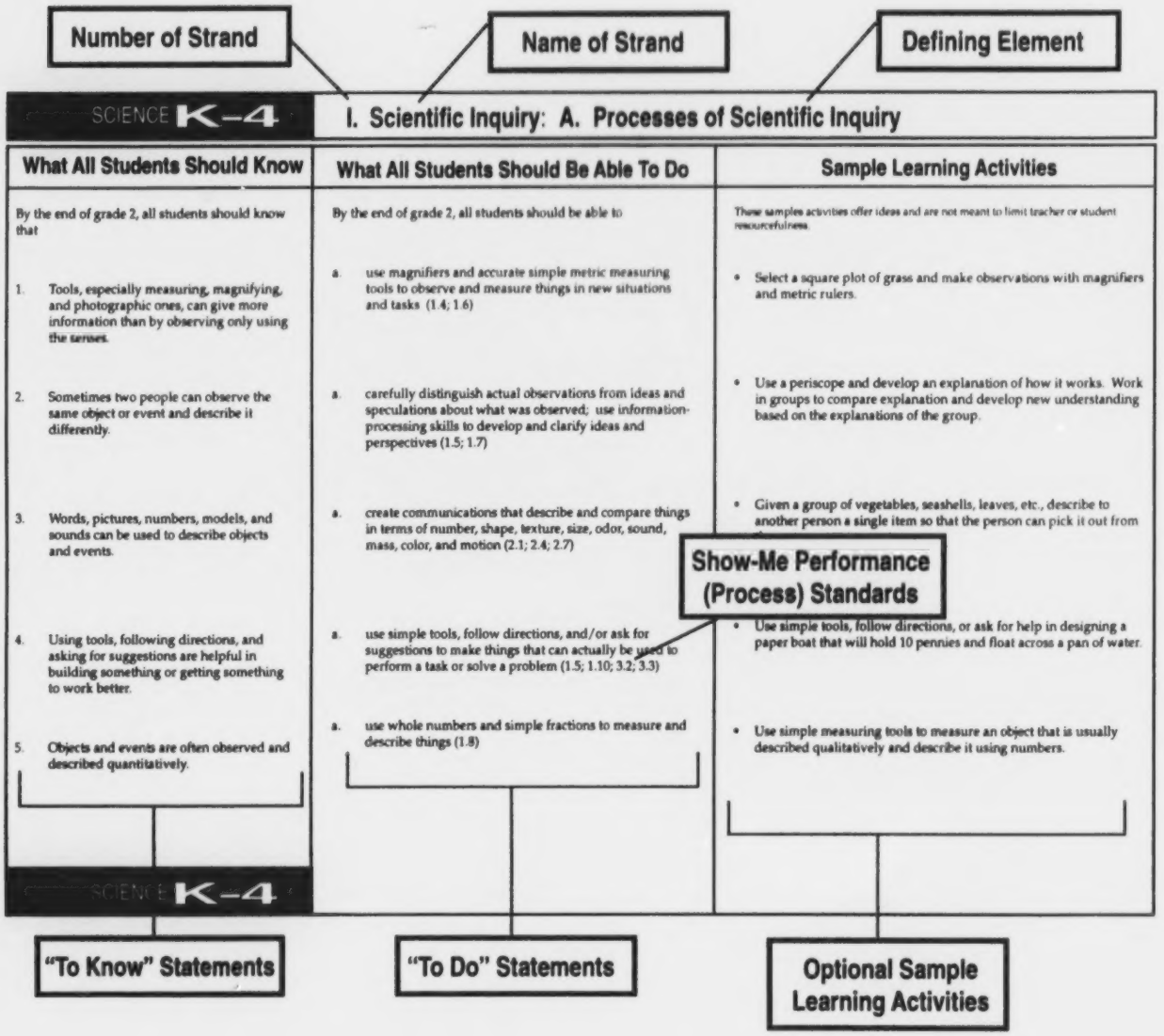
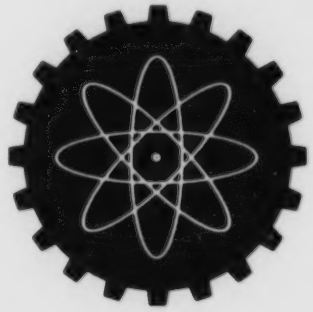

Number of Strand
Name of Strand
Defining Element
SCIENCE K–4
I. Scientific Inquiry: A. Processes of Scientific Inquiry
What All Students Should Know
What All Students Should Be Able To Do
Sample Learning Activities
By the end of grade 2, all students should know that
By the end of grade 2, all students should be able to
These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.
1. Tools, especially measuring, magnifying, and photographic ones, can give more information than by observing only using the senses.
a. use magnifiers and accurate simple metric measuring tools to observe and measure things in new situations and tasks (1.4; 1.6)
• Select a square plot of grass and make observations with magnifiers and metric rulers.
2. Sometimes two people can observe the same object or event and describe it differently.
a. carefully distinguish actual observations from ideas and speculations about what was observed; use information-processing skills to develop and clarify ideas and perspectives (1.5; 1.7)
• Use a periscope and develop an explanation of how it works. Work in groups to compare explanation and develop new understanding based on the explanations of the group.
3. Words, pictures, numbers, models, and sounds can be used to describe objects and events.
a. create communications that describe and compare things in terms of number, shape, texture, size, odor, sound, mass, color, and motion (2.1; 2.4; 2.7)
• Given a group of vegetables, seashells, leaves, etc., describe to another person a single item so that the person can pick it out from
Show-Me Performance (Process) Standards
4. Using tools, following directions, and asking for suggestions are helpful in building something or getting something to work better.
a. use simple tools, follow directions, and/or ask for suggestions to make things that can actually be used to perform a task or solve a problem (1.5; 1.10; 3.2; 3.3)
• Use simple tools, follow directions, or ask for help in designing a paper boat that will hold 10 pennies and float across a pan of water.
5. Objects and events are often observed and described quantitatively.
a. use whole numbers and simple fractions to measure and describe things (1.8)
• Use simple measuring tools to measure an object that is usually described qualitatively and describe it using numbers.
SCIENCE K–4
"To Know" Statements
"To Do" Statements
Optional Sample Learning Activities

I. SCIENTIFIC INQUIRY
(SHOW-ME STANDARDS, SCIENCE 7)



A. Processes of Scientific Inquiry
B. Investigations

K-12 Content Overview:

Scientific inquiry refers to the skills, habits of mind, and attitudes that promote lifelong scientific learning and the ability to apply scientific processes in all facets of life. Traditional approaches to teaching students scientific inquiry often do not give students an accurate perception of the true nature of the processes involved. The result is that many people have the impression that science is nothing more than "doing experiments," and following a rigid sequence of steps referred to as "the scientific method." In reality, the process is far from rigid. More imagination and inventiveness are involved in scientific inquiry than many people realize.

The best way for students to appreciate the true nature of scientific inquiry is for them to participate in scientific investigations based on real-life questions that progressively approximate good science. This approach, however, will require major changes in typical school laboratory activities. Traditional laboratory activities are very unlike real science. They are often teacher-initiated, with the teacher not only specifying the question to be investigated, but also the experimental design, the data to be collected, and ways of organizing and interpreting the data. If students are to understand the process of science, they must make these decisions themselves. Time must be made for revision and repetition of experiments, for presentations of results to other investigators, and even for response to criticism.

Science requires the use of mathematical skills and formulas. Mathematics and science programs should be coordinated so each enhances the learning of the other. By using data from actual science investigations, students will gain experience in dealing with the inconsistencies and errors that occur. Scientific explanations are often clarified through accurate measurements. The metric system should be used consistently throughout the K-12 science experience with emphasis on using the metric system and not the conversion between the metric and other systems.

In addition to in-class laboratory activities that approximate good science, it is important to introduce student investigations. These investigations should become more sophisticated so that before graduating from high school, students should conduct at least one major investigation. Such investigations, whether individual or group, might take weeks or months to conduct, and may take place in or out of school.

I. Scientific Inquiry: A. Processes of Scientific Inquiry

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Tools, especially measuring, magnifying, and photographic ones, can give more information than by observing only using the senses.	a. use magnifiers and accurate simple metric measuring tools to observe and measure things in new situations and tasks (1.4; 1.6)	• Select a square plot of grass and make observations with magnifiers and metric rulers.
2. Sometimes two people can observe the same object or event and describe it differently.	a. carefully distinguish actual observations from ideas and speculations about what was observed; use information-processing skills to develop and clarify ideas and perspectives (1.5; 1.7)	• Use a periscope and develop an explanation of how it works. Work in groups to compare explanation and develop new understanding based on the explanations of the group.
3. Words, pictures, numbers, models, and sounds can be used to describe objects and events.	a. create communications that describe and compare things in terms of number, shape, texture, size, odor, sound, mass, color, and motion (2.1; 2.4; 2.7)	• Given a group of vegetables, seashells, leaves, etc., describe to another person a single item so that the person can pick it out from the group.
4. Using tools, following directions, and asking for suggestions are helpful in building something or getting something to work better.	a. use simple tools, follow directions, and/or ask for suggestions to make things that can actually be used to perform a task or solve a problem (1.5; 1.10; 3.2; 3.3)	• Use simple tools, follow directions, or ask for help in designing a paper boat that will hold 10 pennies and float across a pan of water.
5. Objects and events are often observed and described quantitatively.	a. use whole numbers and simple fractions to measure and describe things (1.8)	• Use simple measuring tools to measure an object that is usually described qualitatively and describe it using numbers.

I. Scientific Inquiry: A. Processes of Scientific Inquiry

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
6. The accuracy of measurements is very important as inaccuracy often produces questionable results.	a. judge whether measurements and computations of quantities are reasonable (1.7) b. compare measurements and computations to typical values with which students have had prior experience (1.10)	• Given a set of data, such as length, area, volume, mass, or time, identify values that are questionable (e.g., values that are much larger or smaller than the others). • Identify the appropriate units of measurements for common objects (e.g., amount of water in a cup, a bucket, or a swimming pool).
7. Additional, more careful observations resolve different explanations for the same event.	a. use simple equipment to observe more detail, measure more accurately, and obtain more information about the environment in order to develop more accurate explanations (1.4; 1.6)	• Participate in a simulated mystery in which incriminating "evidence" can be accurately determined only with the use of a microscope or hard lens.
8. Graphs, charts, maps, equations, and oral and written reports can be used to share the results of a scientific investigation and facilitate its discussion.	a. use a variety of methods, forms, and technologies to organize data into forms that are understandable (1.4; 1.8; 2.1; 2.2; 2.4; 2.7)	• Measure the growth and development of organisms, such as bean plants or mealworms, and communicate observations using graphs, charts, and symbols.
9. Problems can often be solved by physically altering specific components of a mechanical or biological system and observing the consequences.	a. select and apply appropriate technology and common materials for construction and repair of simple things and make safe electrical connections with various electrical devices for the purpose of solving a problem or performing a task (1.10; 2.2; 2.3; 3.5; 3.7; 3.8)	• Construct a "doorbell" for people with hearing impairment using wires, batteries, bulbs, etc.

I. Scientific Inquiry B. Investigations

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The breadth and style of investigations depend on the questions asked.	a. create and refine ideas and questions about the world by asking for information, making careful observations, and trying things out (1.1; 1.2; 1.6; 1.7)	• Observe a discrepant event, such as two balls of similar mass and size that do not bounce the same height, and formulate questions that might lead to an explanation.
	b. plan and conduct a simple investigation that includes fomulating a question, gathering data, and constructing a reasonable explanation.	• Predict what colors are present in the ink of different colored markers. Conduct an investigation and communicate an explanation.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Most experiments involve changing something and then repeatedly comparing it to something similar that has not been changed.	a. plan and conduct a simple experiment that is repeated and properly controlled; then discuss and respond thoughtfully to a variety of conclusions and determine whether the claims are logical arguments based on results of the experiment (1.5; 1.7; 2.3; 3.4; 3.6; 3.7)	• Design two paper airplanes, identical except for one attribute, measure and compare the distance thrown. Discuss whether this is a fair test of how far the planes fly or of which plane is better.

I. Scientific Inquiry A. Processes of Scientific Inquiry

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Various statistical procedures are used to determine characteristics of sets of data as well as to determine the validity of experimental results.	a. apply mathematical procedures to investigations and data sets in order to determine patterns, relationships, and predictions (1.6)	• Use computer software to analyze data from a class experiment using various statistical procedures.
	b. find the mean and median of sets of data, calculate percent and ratios, and determine the units in which the values should be expressed (1.8; 4.1)	• Analyze the running speed of dinosaurs by measuring the distance between footprints on a simulated set of fossil tracks, then calculate the average stride length and the ratio of stride length to leg lengths. Compare these ratios to those of living animals, such as humans.
2. The use of tools allows more sophisticated means of observation and data collection, analyzation, storage, and retrieval.	a. read analog and digital meters that measure length, volume, mass, time, and temperature; use microscopes, cameras, and tape recorders for capturing information; and use computers to locate, select, identify, collect, store, manipulate, and receive information (1.4; 1.8)	• Use an electronic temperature probe connected to a computer to accurately measure and graph temperature changes associated with a variety of insulating materials.
3. The comprehensiveness and sophistication of science are dependent on the ability to determine and use appropriate tools and technologies.	a. using appropriate technologies, inspect, disassemble, and reassemble simple mechanical devices; assess what the various parts are for and what the effect would be of removing or changing individual parts; predict the most likely sources of malfunctions; and select and apply appropriate strategies to correct or prevent such malfunctions (1.6; 3.1; 3.2; 3.3)	• After assessing the racing performance of a variety of toy cars, inspect those with poor performance. Predict the most likely sources of malfunctions and use appropriate strategies and tools (magnifiers, pliers, etc.) to correct the malfunctions.
4. Communication and the open sharing of information and knowledge are essential parts of scientific inquiry.	a. locate, read, listen to, and view various forms of information to interpret and evaluate; organize information in text, tables, and graphs; and use a variety of methods, forms, and technologies to describe the meaning and implications of the information (1.4; 1.5; 1.6; 1.7; 1.8; 2.1; 2.7)	• Organize a science lesson using verbal communication, visual display, and hands-on experiences. Present this lesson to younger students.

I. Scientific Inquiry B. Investigations

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. A valid experiment, or "fair test," involves the manipulation of only one variable, while all others are held constant. Experiments should be repeated many times before accepting the results as true.	a. design and conduct investigations that include an adequate number of repeated trials, unbiased sampling, accurate measurement and record-keeping, and a comparison to a control (1.3; 3.1; 3.2; 3.3; 3.4)	• Design and complete an independent science investigation that includes repeated trials and is properly controlled.
2. Critical analysis of procedures, data, evidence, and conclusions developed during an investigation can be used to judge the quality and validity of the work.	a. analyze and evaluate arguments based on very small sets of data, experiments with few repeated trials, biased samples, or samples for which there was no control sample (1.5; 1.7; 3.4; 3.7)	• Read and analyze selected articles from "supermarket tabloids," which commonly include questionable and highly exaggerated stories, and identify possible sources of error, bias, and incomplete information.

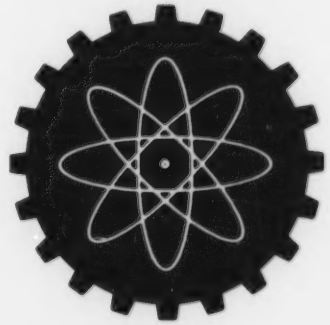
I. Scientific Inquiry A. Processes of Scientific Inquiry

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Investigations may involve mathematical procedures to interpret observations, make predictions, describe sets of data, and determine the validity and significance of experimental results.	a. analyze experimental data to determine patterns, relationships, perspectives, and credibility; use computer spreadsheets, graphing, and database programs to assist in quantitative analysis; and consider the possible effects of measurement errors on calculations (1.7; 1.8; 3.4; 3.6)	• Contact a professional scientist or statistician for advice about the design of an independent project and the statistical analysis of the data. Perform the recommended analysis using appropriate computer software.
2. Publication and presentation of scientific work with supporting evidence are required for critique, review, and validation by the scientific community. The presentation of such work adds to the body of scientific knowledge and serves as background for subsequent investigations in similar areas.	a. present arguments based on scientific investigations that include detailed procedures, graphs and tables, and conclusions; participate in follow-up discussions by responding to alternative positions (1.8; 2.1; 2.3; 2.4)	• Participate in a student seminar in which formal presentations of independent scientific investigations, defense of arguments and conclusions, and critical questions about the methods and conclusions are given.
3. Controlling all variables that might influence an experiment is important. Sometimes it is not possible, for practical or ethical reasons, to control some conditions, but a wide range of observations of natural occurrences can reveal patterns.	a. make systematic observations (nonexperimental) of natural objects or events to discern patterns, formulate explanations, support a thesis, or make predictions (1.1; 1.6; 1.8)	• Design a series of systematic observations that may reveal relationships or patterns of behaviors of an animal species under natural conditions.
4. Technological tools and techniques extend human capabilities to perform investigations in more detail and with greater accuracy and precision.	a. apply technological knowledge and skills to analyze and troubleshoot common mechanical and electrical systems, checking for possible causes of malfunction, and formulate and test logical and creative improvements that prevent future malfunctions. (1.6; 1.10; 3.2; 3.3; 3.6)	• Using basic electrical components and tools, such as soldering gun and pliers, construct a set of light (photocell) probes that can be connected to a computer. Use the light probes to make a photogate timer that will measure the speed of a moving object in a controlled experiment.

I. Scientific Inquiry B. Investigations

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The testing, revising, and occasional discarding of theories lead to increasingly better understanding, but not to absolute truth. New ideas, therefore, usually grow slowly from contributions by many investigators.	a. formulate questions for scientific investigations that indicate conceptual insights and a depth of understanding of the historical development of the idea or issue to be investigated (1.1; 1.9; 3.1; 3.4)	• After conducting a literature search on a topic, contact an expert in the field of interest by e-mail, pose questions for the expert about the historical development of the key ideas involved. Based on collected information, formulate a question for scientific research that indicates an understanding of past research and future directions.
2. Scientists attempt to improve objectivity of data observation and the academic integrity of their research by working in teams and seeking out possible sources of bias.	a. recognize and practice academic integrity while conducting investigations and developing solutions, seeking out sources of personal bias in the design of investigations (3.4; 4.4)	• Design an investigation that involves observation of the behaviors of vertebrate animals. Develop a list of guidelines to avoid biased descriptions of behavior, recognizing that animal behaviors are often mistakenly interpreted in human terms. Submit procedures and collected data to other students for confirmation of objectivity.
3. The testing of a hypothesis requires a structured and rigorous investigative process.	a. design and conduct a full scientific investigation including a comprehensive review of related literature: experimental design that is thoughtful and well-controlled, with adequate repeated trials; accurate measurement of data; some form of statistical treatment and display of data; thoughtful interpretation of data; and communication and defense of logical arguments supported by the finding (1.1; 1.2; 1.3; 1.8; 2.1; 2.2; 3.1; 3.2; 3.3; 3.4; 3.5; 4.1; 4.4)	• Design and conduct an independent science project following all of the guidelines of a nationally recognized science fair. Submit the project for competition in the science fair.

II. SCIENTIFIC RELEVANCE
(SHOW-ME STANDARDS, SCIENCE 8)



A. The Nature of Technology
B. Historical Perspective
C. Science as a Human Endeavor

K-12 Content Overview:

As long as there have been people, there has been technology. Indeed, the techniques of shaping tools are taken as the chief evidence of the beginning of human culture. On the whole, technology has been a powerful force in the development of civilization, all the more so as its link with science has been forged. Science and technology—like language, ritual, values, commerce, and the arts—are intrinsic parts of a cultural system that both shape and reflect the system's values. Consider, for example, how new ideas are limited by the context in which they are conceived. These ideas are often rejected by the scientific establishment; sometimes spring from unexpected findings, and usually grow slowly through contributions from many different investigators. Historical episodes such as Galileo's efforts to change perceptions of Earth's place in the universe, Newton's demonstration that the same laws of motion apply in the heavens and on Earth, Lyell's careful documentation of the age of the Earth, and Pasteur's identification of infectious disease with microscopic organisms are all concrete examples of how scientific theory and technology interact with social and political realities within a specific period of time. These examples also illustrate the power of individuals to conceptualize and change our understanding of the world around us.

Even in today's world, technology is a complex social enterprise that includes not only research, design, and crafts but also finance, manufacturing, management, labor, marketing, and maintenance. In the broadest sense, technology extends our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; to reach farther with our hands, voices, and senses. We use technology to try to change the world to suit us better. The results of changing the world are often complicated and unpredictable. They can include unexpected benefits, unexpected costs, and unexpected risks. Anticipating the effects of technology is, therefore, as important as advancing its capabilities.

(Benchmarks for Science Literacy, AAAS 1993)

II. Scientific Relevance A. The Nature of Technology

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Tools that have been invented affect all areas of life.	a. develop realistic strategies and use various objects to solve simple environmental or social problems encountered in school or community (3.1; 3.2; 3.3)	• After saving milk jugs for a period of time, discuss the benefits of these devices and the problems that have resulted due to difficulties with disposal. Develop reasonable strategies to bundle them and transport them to a recycling center.
2. When people want to build something or try something new, they should try to figure out ahead of time how this might affect all living things and environments.	a. predict, analyze, and evaluate the potential effects of technological solutions to simple problems on other people or the environment, considering such issues as costs, benefits, and consequences (3.6; 3.7; 3.8)	• Considering a specific technological solution to a problem, such as covering the playground with a rubber surface to prevent injuries, generate lists of possible positive and negative consequences of this solution.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
3. Technology extends the ability of people to change the way things work.	a. develop several alternative strategies to solve existing and potential environmental or technological problems, analyze and evaluate the alternatives by comparing strengths (such as safety or ease of use) and weaknesses (such as cost or appearance), and determine the best solution (3.6; 3.7; 3.8)	• Working in groups, design a new communication system for the school to replace the existing intercom system. Compare the alternative solutions from each group and generate a list of strengths and weaknesses of each one.
4. Technological solutions to problems often have drawbacks as well as benefits.	a. predict possible negative consequences, to people, other organisms, or the environment, of technological solutions to specific problems (3.6; 3.7; 3.8; 4.7)	• Considering a specific technological solution to a problem, such as controlling insects in farm crops, list possible alternative solutions and drawbacks of each.

II. Scientific Relevance B. Historical Perspective

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Throughout human history, technological innovations have played an important role in improving the quality of life.	a. investigate, discuss, and raise questions about the past, and possible future, contributions of science and technology to individuals and society (1.2; 1.9; 2.3; 2.4; 3.4; 3.6)	• Examine a variety of old technological devices and speculate what the object was used for, how it helped people, and what problems it might have caused.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Advances in science and technology are occurring at a faster rate today than in the past.	a. identify some reasons/causes for recent increases in technological advances	• List some of the major inventions within a 20-year period of the 19th century and compare this to the major technological advances of the past 20 years.

II. Scientific Relevance C. Science as a Human Endeavor

By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Science is a way to solve problems; everybody can do scientific activities, discover some things about nature, and invent things and ideas.	a. work with a group to solve a problem, giving due credit to the ideas and contributions of each group member (2.3; 3.6; 4.4; 4.6)	• Read a variety of short stories and discuss science as a human endeavor in which men and women from different cultures have participated.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Science requires many different kinds of activities, involving men and women of all ages and backgrounds.	a. recognize the various ways in which science and technology impact on all career and occupational areas (4.3; 4.8)	• Use a variety of resources (e.g., books, films, on-line resources guest scientists, field trips to describe the many different kinds of science-based occupations and the diversity of individuals in the scientific community.

II. Scientific Relevance A. The Nature of Technology

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The issues related to science, technology, and society are often complex and involve risk/benefit trade-offs.	a. analyze, evaluate, and communicate both benefits and possible risks to health, society, and the environment associated with investigations and technological advances reported in the media (1.1; 1.2; 1.7; 1.9; 2.1; 2.2; 2.3; 3.1; 3.5; 3.6; 3.8; 4.1; 4.3; 4.4; 4.6)	• Explore what conditions were like under different technological circumstances in the past (e.g., inadequate control of sewage, limited means of preserving food, inefficient methods of heating and lighting houses). Identify the products, processes or technologies that have been developed to improve these situations and consider whether the short-term and long-term benefits outweigh the short-term and long-term risks.
2. Breakthroughs in science often lead to advances in technology, and improved technological equipment leads to more accurate data collection in scientific inquiry.	a. identify and analyze ways in which advances in science and technology have affected each other and society (1.1; 1.2; 1.6; 1.7; 1.9; 3.8)	• Research and identify the advances in surgical procedures that have resulted from new technologies (such as laser surgery, lapiscopic surgery, CAT scans, MRIs).

II. Scientific Relevance B. Historical Perspective

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Important contributions in science have been made by many different people, in different cultures, and at different times. Their places of work include offices, classrooms, laboratories, farms, factories, and natural field settings everywhere.	a. identify the background qualifications and training that are needed in order to have careers related to science and technology (4.8)	• Research the life, work, and contributions of a contemporary or historical scientist. Compare the background qualities and other factors that influenced the work and training of the scientist.
2. Some people (e.g., women and minorities) have sometimes been discouraged or denied the opportunity of participating in science because of education or employment prejudices and restrictions.	a. describe some of the funding sources that can be used to finance education and training in science and technology (1.2; 1.4; 1.7)	• Explore the strategies that have been used in Missouri to increase the representation of women and minorities in the scientific workforce.

II. Scientific Relevance C. Science as a Human Endeavor

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Scientific ethics require that scientists must not knowingly subject coworkers, students, human research subjects, the neighborhood, or the community to health or property risks without their knowledge and consent.	a. evaluate possible risks to classmates, research subjects, or the community associated with their own independent investigations (1.2; 1.4; 1.7; 1.10; 4.3; 4.4; 4.7)	• For your own investigations, submit written justification for the investigation, forms for permission to use intended sites or property, and consent forms from human participants. Predict both positive and negative outcomes possible in any experiment.
2. Social, cultural, environmental, and economic factors all influence which science and technology will be undertaken and used. Society and the environment are directly influenced by the discoveries of science and products of technology.	a. analyze and evaluate the economic, political, social, ethical, and aesthetic constraints that might affect progress with specific scientific technological endeavors (3.1; 3.4; 3.5; 3.6; 3.8; 4.1)	• Work in teams to investigate current political, budget-related events and their impact on funding of scientific endeavors.

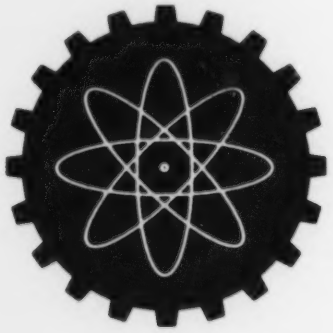
What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Social and economic forces, such as personal values, consumer acceptance, patent laws, the federal budget, current regulations, media attention, and economic competition strongly influence the direction of progress of science and technology. Progress in science and technology, on the other hand, often result in many ethical, legal, and public policy issues.	a. discuss the scientific, technological , and political aspects of major challenges to society. Describe how each of these aspects influences public policy formulation in dealing with the challenges (2.3; 2.4; 4.1; 4.3; 4.7)	• Form a mock presidential cabinet and prepare arguments to be presented to the president expressing the opinion of each cabinet position on the issue of funding for the National Science Foundation in the next annual budget.
2. Human beings have a huge impact on other species, their environments, and technology. These impacts include reducing the amount of habitat available, interfering with food sources, changing the temperature and chemical composition of their habitats, introducing foreign species, and altering organisms directly through selective breeding and genetic engineering.	a. analyze and evaluate how specific technological solutions may impact the environment in areas such as habitat loss, disruption of the food web, and temperature and chemical changes (1.1; 1.2; 1.6; 1.7; 3.1; 4.1)	• Working in groups, explore examples of the environmental impact of energy sources used extensively in the past and the societal and technological changes which brought about a change in their use. Using this as background, propose ways to balance current energy needs with reduced environmental impact.

II. Scientific Relevance B. Historical Perspective

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Scientific theories are developed based on the body of knowledge that exists at any particular time. The driving force to find what is really true motivates scientists to test the validity of these theories and as a result the mysteries of nature are continuously probed and explained as new theories are created and old theories discarded.	a. identify and analyze theories that are currently being questioned, and compare them to new theories that have emerged to challenge the older ones (1.2; 1.5; 1.6; 1.7; 1.9; 2.4; 3.7; 4.1)	• Identify a scientific theory that is currently being modified or debated based upon new data being gathered by the scientific community (e.g., structure of the atom, origin and evolution of the universe, formation of Earth's geological features). Discuss the interplay that exists between theory and the new information.
2. The history of scientific thought spanned many cultures and centuries. The early Egyptian, Greek, Chinese, Hindu, and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions. Modern science is based on traditions of thought that came together in Europe about 500 years ago. All cultures now contribute to that tradition.	a. identify and analyze various scientific concepts, inventions, and technological innovations that have been developed by different cultures from around the world; discuss the influence of prevailing contemporary thought on the acceptance of these concepts, inventions, and innovations by other scientists and society (1.2; 1.5, 1.6; 1.7; 1.8; 1.9; 2.1; 2.2; 2.3; 2.4; 4.1)	• Develop a timeline of the major scientific and mathematical concepts and/or technological inventions from the early Egyptian, Greek, Chinese, Hindu, and Arabic cultures.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Scientists make mistakes like all people. Deliberate deceit, however, is rare and is likely to be exposed eventually by the scientific enterprise itself.	a. identify, discuss, and respond thoughtfully to information from credible sources, such as scientists making claims in their areas of expertise, and from sources of questionable credibility, such as people whose own personal, institutional, or community interests are at stake (1.5; 1.7; 1.8; 2.1; 2.2; 2.3)	• Read a collection of articles, including peer-reviewed articles from science journals, newspaper articles, and "supermarket tabloid" articles, about a science-related issue such as the New Madrid fault. Analyze the credibility and documentation of each article.
2. Research funding comes from various federal government agencies, industry, and private foundations. Research grant proposals are written to promote research that is relevant, well-designed, cost efficient, and well-supported by previous research.	a. analyze a scientific research grant proposal and defend or dispute, in an organized and convincing way, sections that promote the proposed research (1.2, 1.5; 1.7; 1.8; 2.1; 2.2; 2.4; 4.1)	• Prepare a mock grant proposal, justifying and promoting the proposed research, for funding from a government agency or private sector.

III. MATTER AND ENERGY
(SHOW-ME STANDARDS, SCIENCE 1)



A. Properties, Characteristics and Structure of Matter
B. Characteristics, Forms and Sources of Energy
C. Interactions of Matter and Energy

K-12 Content Overview:

The physical universe is composed of matter. Students must develop a basic understanding of nature, structure, and properties of matter. They should also experience and learn how matter is changed and how the uses of matter are related to its properties. Every physical object in the universe consists of relatively few types of matter called elements. Elements consist of unique kinds of atoms that combine in different ways to form substances. The arrangement of the outermost electrons in an atom determines how atoms bond to form materials. Each of the elements consists of only a few naturally occurring isotopes. Every substance can exist in a variety of different states, depending on temperature and pressure.

The flow or energy between objects, between different parts of the biosphere and from one part of the universe to another drives the continual process of change occurring throughout all physical systems (biological, chemical, geological). Society needs abundant energy sources to improve its economic productivity and the quality of life. Students need to understand the fundamentals of energy and the natural laws that govern force and motion. Energy occurs in several forms: chemical, electrical, electromagnetic, mechanical, nuclear, and thermal, which are interchangable. Most of the processes in the universe, from exploding stars to the operation of machines, involve the transformation of energy from one form to another. This transformation usually produces some heat energy that is lost by radiation or conduction. Whenever the amount of energy in one place or form diminishes, the amount in another place or form increases by an equivalent amount. Energy as well as matter occurs in discrete (quantum) units.

III. Matter and Energy A. Properties, Characteristics and Structures of Matter

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Observable properties are used to identify objects.	a. identify physical properties of objects and sort according to specific properties (1.3; 1.8; 4.1)	• Sort common objects (buttons, rocks, blocks) using specific properties. Describe what properties were used.
	b. identify physical properties of objects that are detected using the senses (1.3; 2.4; 4.1)	• Use granular Jell-O and glue to make "scratch and sniff" stickers or pictures. • Use feely boxes to describe and predict the object they are holding without using their eyes. • Investigate colors by mixing new colors in a variety of mediums (e.g., food colors in frosting or water).
	c. demonstrate that magnification enhances the ability to observe the properties of small objects (1.4; 1.6; 2.1)	• Inspect several objects with and without a hand lens. Discuss and describe the increased level of detail that can be observed with magnification.
	d. describe a material as its form and size is changed (1.6; 2.2; 3.5)	• Observe and describe changes in a material (e.g., paper, a leaf) as it is cut into increasingly smaller pieces. Use a magnifying glass to compare characteristics of the smallest segments with the original.
2. Matter has physical properties that can change.	a. identify ways heat and light affect common objects (1.3; 3.5)	• Describe the physical changes that occur when newspaper is left in the sun, potato slices are left exposed to air, cereal left in a bowl of milk, etc.
	b. compare and contrast the physical properties of a solid and liquid of the same material (1.2; 1.4; 1.6; 2.3)	• Describe and compare the physical properties of water and ice.
3. Mixtures are composed of different kinds of matter, each with distinct properties.	a. separate, sort, or group the components of a mixture by their properties (1.3; 1.4; 1.6)	• Prepare a trail mix, or tossed salad. Discuss how the properties of the mixture are different from the properties of each component. Design a way for the mixture to be separated.

III. Matter and Energy A. Properties, Characteristics and Structures of Matter

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
4. Matter is anything that has mass and volume and is composed of smaller parts.	a. select and classify a variety of common materials and objects as being composed of one substance or more than one substance (1.2; 2.3; 3.5)	• Identify things that are combinations of substances (e.g., bricks, concrete, cakes, cookies).
	b. refine and adapt the parts of objects to create a new object (1.4; 1.6; 3.1; 4.6)	• Identify the parts used to make a lamp, coffee pot, sofa, etc.
	c. demonstrate the mass of an object equals the sum of the masses of its parts (1.2; 2.4)	• Construct an object out of Lego blocks, take it apart, and rearrange the parts to make a new object. • Mass an object made of Tinker Toys, Lego, Lincoln Logs, etc. Take the object apart and total the mass of each component.
5. Substances can occur either in pure form or as a mixture.	a. predict the properties of a mixture given the concentration of ingredients (1.6; 2.3; 3.5)	• Prepare different concentrations of Kool-Aid, Jell-O, etc. Observe and compare differences in the properties of these mixtures to the concentrations used (color, taste, etc.).
	b. identify the factors that determine the choice of materials for a particular purpose (1.6; 2.3; 3.2; 3.3; 3.5)	• Investigate the properties of devices that make them useful for a given purpose in the real world. Use this knowledge to design a common object or to solve a problem (types of clothing, types of furniture, etc.)
6. Physical properties of matter can change.	a. use magnifiers, measuring tools, and other technology to identify the properties of matter or objects (1.2; 1.3; 1.7)	• Inspect and describe the physical characteristics of salt, flour, sugar, etc. Expand the description by using magnification.
	b. select and apply strategies to change matter by heating or cooling predict what changes will occur (1.3; 1.6; 2.4; 3.5)	• Investigate how much energy it takes to change water to ice or steam.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
	c. observe and describe the effects of the environment on a variety of objects (dissolving, weathering, shrinking, melting, rusting) (1.6; 2.1)	• Observe the long-term effects of the environment on a block of salt, a patch of snow, an exposed piece of iron, etc., and describe the changes.

III. Matter and Energy B. Characteristics, Forms and Sources of Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The sun is the primary source of light and heat for the Earth.	a. predict how sunlight will affect the temperature of air and water (1.2; 1.4, 1.6; 4.1)	• Record and compare the temperatures of air and water at various times during the day, on cloudy and on clear days.
2. Energy can be converted into different forms.	a. identify and describe the transformation of energy from one form to another (1.2; 1.4; 3.5; 4.1)	• Use a lamp to demonstrate how electricity is transformed to light and heat energy.
3. Sound is a form of energy that results from vibrations in matter. Sound has the qualities of loudness and pitch.	a apply knowledge of sound, learned from altering loudness and pitch (1.2; 1.3; 1.6)	• Identify sounds around the school and identify the source of the vibrations. • Design a phone system from string/cans or funnels/tubing. Explain why it works.
	b. change the pitch of a stringed instrument by changing the length of the strings and the loudness by the energy of the vibration (1.1; 1.2; 1.3; 1.6)	• Investigate the kinds of sounds produced from different lengths of string, different amounts of water in a bottle, or different types of bells and predict what sounds would be produced with additional variations.

SCIENCE K-4

III. Matter and Energy B. Characteristics, Forms and Sources of Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
4. Some of the sun's light is transformed into heat when it hits objects.	a. predict the effect of sunlight on various objects, liquids, and solids (1.6; 2.3; 3.5)	• Measure/record how the sun's light is transformed into heat (e.g., asphalt road, concrete, dark clothing). Demonstrate ways this is useful (e.g., melt ice faster, run a solar calculator, make sun tea, warm a room).
5. Electricity can be converted into light, heat, sound, magnetism, or mechanical motion.	a. apply knowledge of simple circuits to create a new circuit that involves more components (1.10; 3.5; 4.1)	• Use a battery, wires, and a light (or a motor or buzzer) to demonstrate the requirements for a complete circuit. Observe the effect of interrupting the circuit.
6. Friction produces heat.	a. identify and consider a variety of methods that produce heat by friction (1.2; 1.3; 1.6; 3.5)	• Investigate how heat is produced by friction. Identify the source of friction and the amount of heat generated (rubbing hands together, rubbing pieces of metal together, shaking sand in a can, etc.).
7. Sound travels at different rates through different materials.	a. select and apply technology and other resources to show that sounds travels through some materials better than in others (1.4; 2.3; 3.5; 4.6)	• Use a tuning fork to show the vibrations produced on a rubber membrane, on metal, or on wood. • Use a tuning fork to show how sound travels through water. Relate this to animals who use sonar.
8. Light spreads from a source and travels in straight lines. Light can be transmitted, reflected, refracted, or absorbed by different materials.	a. predict which materials will reflect, which will absorb, and which transmit light (1.2; 1.6; 2.3; 3.1)	• Use glass, clear plastic, cloudy plastic, paper, etc. to determine which ones transmit light, partially transmits light, or casts shadows. • Observe the changes in shadows at different distances from a light source and different angles between the light source and objects. • Manipulate a reflected beam of light through a maze.
	b. use lenses or water to observe examples of the bending of light; use mirrors or a water surface to show how light is reflected (1.6; 3.5)	• Generalize where a light source is when shadows are shortest/longest, where a fish is when seen from shore, etc.

III. Matter and Energy C. Interactions of Matter and Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Objects that give off light may also give off heat.	a. identify and consider a variety of light sources to determine which give off heat (1.1; 1.3; 1.6; 2.3; 3.5; 4.1)	• Compare the heat from several light sources (e.g., incandescent bulb, fluorescent bulb, sun, halogen bulb).
2. Heat causes materials to increase in temperature and feel warmer, or change state (gas, liquid, or solid).	a. select and apply strategies to show how heat causes materials to increase in temperature and makes it feel warmer (1.2; 1.3; 1.6; 2.3; 3.5; 4.1)	• Use a light bulb and a thermometer to compare how heat flows through different materials (e.g., aluminum, air, colored paper, cloth).
By the end of grade 4, all students should know	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
3. Warm objects lose heat to cooler ones until they reach the same temperature.	a. identify which materials will become warmer and which materials will become cooler when mixed (1.2; 1.6; 1.10)	• Explore how heat flows from warm objects to cooler ones, (ice cubes in water) to equalize the temperature.
4. Different types of matter conduct heat at different rates.	a. identify characteristics of conductive materials and of insulative materials (1.2; 1.6; 3.5)	• Investigate different materials used to make cups to determine which are good conductors of heat and which are good insulators.

III. Matter and Energy A. Properties, Characteristics and Structure of Matter

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. In a closed system, matter is conserved during any physical or chemical change.	a. use laboratory investigations to demonstrate the formation of new materials and demonstrate the conservation of matter (1.3; 1.6; 2.4)	• In laboratory investigations, demonstrate precipitation, gas evolution, electrolysis of water. Compare the mass of the substances before and after a chemical change.
2. Some physical properties depend on the amount of matter present while other properties do not.	a. identify those properties that are characteristic of a substance and those that depend on the amount of substance present (1.2; 1.6; 1.8; 2.3; 3.2; 3.3)	• Design and perform experiments that identify the melting point, density, mass, volume, etc. ,of water.
3. Almost all matter is derived from naturally occurring elements. Each element is made of atoms that bond together to form molecules.	a. investigate changes of state of water and use the particulate model to describe these changes (1.1; 1.2; 1.3; 1.6; 1.7; 3.2; 3.3)	• Construct models of water, sodium chloride, or hydrogen and discuss the relationship of the structures to the physical properties of the substance.
4. The arrangement, motion, and interaction of molecules determine the physical state for the matter.	a. investigate property changes as a result of changes in the physical state of a substance (1.1; 1.2; 1.3; 1.6; 1.7; 3.2; 3.3)	• Demonstrate the volume changes due to changes in the physical state of iodine, water, or dry ice.
	b. investigate how the rate of change of state is affected by the addition or removal of heat (1.1; 1.2; 1.3; 1.6; 1.7; 3.2; 3.3)	• Measure and compare the rate of melting of ice on different colored fabrics exposed to sunlight.
5. Compounds can be analyzed and separated by making use of their unique chemical and physical properties.	a. separate natural or synthetic substances into their component compounds (1.3; 1.4; 3.5; 4.6; 4.7)	• Determine the most appropriate methods to separate milk, blood, sea water, processed foods, paints, cosmetics, etc. into their component parts.
	b. investigate and report why certain components of mixtures are reported to the public and how they are used to monitor health problems and/or environmental pollutants (1.2; 1.3; 1.8; 2.1; 3.2; 3.3; 4.1)	• List the fat content in a variety of meats, canned vegetables, breads, snacks, etc., and identify the potential health problems/benefits associated with eating those foods.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
6. Chemical changes occur at the atomic level to form new substances with different properties.	a. identify chemical changes in common objects as a result of interactions with heat, light, air (1.6; 1.1; 3.1; 3.5)	• Identify and describe the chemical changes in various materials by observing everyday events (nail left in water, cooking vegetables).
7. Solution properties depend on concentration and nature of the substances involved.	a. identify the components of a solution, demonstrating the use of ratios and percents in preparing different concentrations of the solution, and compare the properties of different concentrations of the solution (1.2; 1.6; 1.8; 3.1; 3.5)	• Mix four different concentrations of Jell-O solutions, reporting the ratios of the components, and compare the taste, viscosity, color, etc., of the four solutions.

III. Matter and Energy B. Characteristics, Forms and Sources of Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Most processes involve energy transformation with the release of heat. However, the total amount of energy remains constant.	a. measure and quantitatively compare the heat changes involved in an energy transformation (1.2; 1.3; 1.6; 1.8; 2.4; 3.5)	• Measure and compare the temperature differences in incandescent and fluorescent light bulbs of various wattage when they are on.
2. The electromagnetic spectrum consists of energy bands of visible and nonvisible wavelengths. White light from the sun consists of a mixture of wavelengths and energies in the visible part of the electromagnetic spectrum.	a. identify the wavelengths and energies in the visible part of the electromagnetic spectrum (1.3; 1.6; 3.5) b. identify and discuss the use/misuse of the non-visible part of the electromagnetic spectrum (1.7; 1.10, 2.4; 3.8; 4.7)	• Use a prism or diffraction grating to separate white light. Explain the colors and their order in terms of their wavelengths and energies. • Identify and discuss the use/misuse of microwaves, UV light, and x-rays.
3. Electrical energy is transferred by the movement of electrons driven by a voltage through a complete circuit and is extremely useful to humankind.	a. understand the advantages and disadvantages of series and parallel circuits (1.2; 1.3; 1.4; 1.6; 1.10; 3.7) b. compare various sources of energy for the generation of electric power (1.10; 2.4; 3.8; 4.7)	• Design and demonstrate simple series and parallel circuits. Discuss the advantages and applications of each. • Research and discuss the advantages and disadvantages of the use of coal, natural gas, wood, and oil in the generation of electricity.
4. Static electricity is potential energy stored in a collection of separated negative and positive charges.	a. predict specific conditions that will cause static electricity (1.2; 1.6; 2.4; 3.5) b. understand applications and hazards of static electricity (1.10; 2.4; 3.8; 4.7)	• Generate static electricity from various sources (e.g., rubbing fur on plastic rods, combing hair) and investigate conditions under which this happens. • Discuss the hazards of a build up of static electricity (around computers, lightning).
5. Chemical energy is stored in chemical bonds between atoms in the elements and compounds.	a. identify sources of chemical energy used in commercial and industrial activity and in life processes (1.7; 1.10; 2.4; 3.8; 4.7)	• Identify sources of chemical energy encountered every day (batteries, food) and discuss its importance to life and society.

III. Matter and Energy C. Interactions of Matter and Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Energy is required to produce changes in matter and do to work.	a. design, conduct, and communicate about an investigation that shows the relationship between energy and changes in matter (1.3; 1.6; 2.1; 2.7; 3.8)	• Measure the amount of energy required to melt a known mass of ice and compare it to the energy needed to boil water.
2. Heat energy can be transferred by conduction, convection, or radiation.	a. discuss the roles of radiation, convection, and conduction in weather changes (1.2; 1.6, 2.3; 2.4; 3.5; 4.6)	• Use weather maps and reports over an extended period of time to show the effects of uneven heating and cooling of Earth's surface on weather.
3. The interaction between matter and energy can result in changes in electronic, atomic, and molecular motion.	a. explain how an energy source interacts with and causes changes in different materials (1.3; 2.1; 2.4; 3.5; 4.1)	• Use measurements to show how microwave heating affects various materials such as plastic, glass, or water. Explain the results in terms of changes in electronic, atomic, or molecular motions.
4. Different materials have different electrical resistance. Resistance converts electric energy into heat energy.	a. explain the characteristics of a substance that makes it a good conductor or insulator (1.3; 2.1; 2.4; 3.5; 4.1)	• Use various materials in a simple circuit to show the difference between conductors and insulators and compare the efficiency of electrical conductors.
5. Energy travels through matter as waves.	a. identify waves as mechanical or electromagnetic and identify common wave properties (1.2; 1.6; 1.7; 3.5)	• Classify waves as mechanical (sound, tidal, earthquake) or electromagnetic (radio, sunlight).
	b. discuss how waves interact with barriers and each other (1.6; 2.3; 3.5)	• Generate waves in a water tank to demonstrate common wave properties when they interact with barriers (such as sides of tank, rocks, slits in paraffin) and each other.

SCIENCE 5–8

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The Periodic Table organizes the elements according to their physical properties and chemical reactivity.	a. demonstrate how the Periodic Table can be used to predict the properties of elements and determine trends in these properties as they relate to the physical world (1.6; 2.4; 4.1)	• Use any one family of elements on the Periodic Table to show what common reactions or properties exist in related compounds and what uncommon or unusual differences exist. • Use atomic mass data to determine a substance's molar mass, percent composition, etc. • Conduct appropriate investigations to verify various scientific laws (e.g., conservation of matter, definite composition, multiple proportions). • Investigate and report on the historical development of the modern Periodic Table.
2. Models can be used to represent elements, compounds, and ions.	a. describe the molecular, atomic, and ionic make-up of a variety of substances; use the appropriate formula to represent these substances; explain how the arrangement and motion of molecules determine a variety of biological, chemical, and physical phenomena (1.6; 1.8; 2.2; 3.5) b. use bonding diagrams to show ionic and covalent bonding and to predict the outcome of a chemical reaction (1.5; 1.8; 2.2; 3.5)	• Construct models of carbon dioxide, nitrogen, butene, and butyne. Identify single, double, and triple bonds and draw the structural formula for each. • Construct models or draw structural formulas representing the substances found in household products. • Observe and record the patterns of some of the properties of benzoic acid, magnesium chloride, potassium iodide, etc., that distinguish ionic compounds from covalent compounds.
3. Solution properties depend upon the concentrations, properties, and interactions of the solutes and solvents.	a. analyze and discuss the types and concentration of solute or solvent that affect the rate of solubility, acidity, viscosity of the solution (1.3; 1.6; 1.8; 2.4; 3.2; 3.3; 4.1)	• Investigate and report on examples of how different types and concentrations of solutions are used (de-icing roads, windshields, aircraft). • Conduct appropriate investigations to verify the type of solution (acid, base, or neutral) and concentration of household products. • Investigate and report the environmental impact of various types and concentrations of solutions.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
4. The particulate model describes the electrically neutral atom.	a. describe the components of the modern model of an atom and how they are related (1.4; 1.6; 2.4; 4.1)	• Research the development of the understanding of the atom from the early Greeks to modern scientists. Report the discoveries that influenced the development of models of the atom.

III. Matter and Energy B. Characteristics, Forms and Sources of Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Chemical and nuclear reactions provide energy that sustains industrial, life, and social processes.	a. conduct an investigation on how energy has been obtained/used and the consequences of its use (1.1; 1.2; 1.3; 1.4; 1.6; 1.10; 3.8; 4.7; 1.9)	• Explore examples of the environmental impact of energy sources used extensively in the past such as peat, wood, or water and the societal and technological changes that brought about a change in their use. Using this as background, propose approaches to balance current energy needs with reduced environmental impact.
2. The amount and rate of energy change for any process can be quantified.	a. determine the amount of heat required to change the temperature or state of a substance (1.2; 1.3; 1.7, 2.7; 3.5)	• Measure the heat released when the chemical energy stored in fuels or foods is released upon combustion. Discuss and account for the energy balance in the process.
3. Energy can be transfered as waves. The frequency and wavelengths of the waves are affected by the relative motion of the source and receiver.	a. explain the Dopplar Effect and identify some of its applications (1.10; 2.4; 4.1)	• Demonstrate the Dopplar Effect by using a decibel meter to measure the apparent change in the sound of a train whistle as it passes. Research the application of the Dopplar Effect to the measurement of distances and relative movement of stars or weather systems.
4. Voltage and resistance affect the flow of electric current in a circuit.	a. design an electrical circuit (1.3; 2.3; 3.2; 3.3)	• Construct parallel or series circuits and apply Ohm's Law to evaluate the components of the circuits. • Research and report the appropriateness of the use of series or parallel circuits in the home and industry.

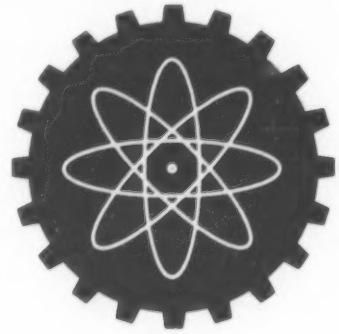
III. Matter and Energy C. Interactions of Matter and Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Chemical, physical, and nuclear changes involve energy transfers.	a. describe how energy is involved in chemical, physical, and nuclear changes (1.6; 1.8; 2.1; 2.4; 3.5)	• Determine the amount of heat required to change the temperature or state of water.
2. Heat flows from a body of a higher temperature to one of a lower one.	a. distinguish the direction of thermal energy in natural processes (1.3; 1.10; 3.5)	• Measure the heat transfer by conduction, convection, or radiation; discuss the advantages of each method and identify its use in the household.
	b. investigate the relationship between heat and work (1.3, 1.4, 1.8, 2.1, 2.4, 3.5, 4.1)	• Diagram and explain how the interior of a refrigerator is cooled.
3. Phase changes can occur due to a quantitative transfer of heat energy.	a. investigate phase changes that are induced by adding/subtracting heat energy and explain, using the particulate model, how the interaction of atoms or molecules during a change of state affects the properties of the substance (1.2; 1.3; 1.6; 2.1; 2.4; 3.5)	• Identify and measure the energy transfers occurring during the making and freezing of homemade ice cream. • Drop an ice cube in water. Monitor the temperature of the water every 10 seconds. Plot a "temperature vs. time" graph and compute the heat of fusion of water.
4. The interaction of energy and matter may result in the formation of heat or other energy forms.	a. describe the interaction of energy waves with the materials of man-made devices (1.3; 1.6; 1.10; 2.1; 2.4; 3.5; 4.1)	• Investigate the interaction of energy in electric heaters, solar cells, remote control units, etc. Discuss the efficiency of such devices.

III. Matter and Energy C. Interactions of Matter and Energy

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
5. Nuclear reactions can change matter into energy and vice versa. The total quantity of matter and energy is conserved.	a. analyze the amount of energy contained in the mass of substance (1.2; 1.3; 1.6; 3.5; 4.1)	• Compare the energy released from 1 gram of a substance burned as a chemical fuel to the energy available if the same mass were converted to energy through nuclear decay ($E = mc^2$).
6. Solar energy travels through space, is distributed on Earth by radiation, conduction, or convection, and powers atmospheric and oceanic circulation.	a. explain how the transfer of energy by air and ocean currents regulate the physical environment of the Earth (1.2; 1.3; 2.1; 2.4; 3.3; 4.1)	• Investigate and describe the effects of world atmospheric circulation or oceanic circulation on the temperatures of different parts of the world.

IV. FORCE, MOTION AND MECHANICAL ENERGY
(SHOW-ME STANDARDS, SCIENCE 2)



A. Relative Motion
B. Types and Properties of Forces and Motion
C. Interactions of Forces and Motion

K-12 Content Overview:

Motion is as essential to understanding the physical world as matter and energy. Nothing in the universe is at rest and even things that appear to be at rest move. The description of how objects move depends on the frame of reference, but everything moves with respect to the sun and stars. Motion is described in terms of distance, displacement, speed, velocity, and acceleration. There are different types of motion, each with important properties, that can be combined into more complex forms. Types of motion include constant speed in a straight line, constant speed in a circle, acceleration in a straight line, and acceleration in a circular path. Relationships among these quantities are more easily interpreted and used to solve problems by means of graphical techniques involving slopes and areas under curves.

Four fundamental types of forces exist in the universe: gravitational, electromagnetic, strong nuclear force, and weak nuclear force. All other forces can be classified in terms of these four. Changes in the motion of objects are due to the effects of these forces. The size and direction of a force are important in order to determine the effect on the motion of an object. More than one force can act on an object at the same time and can make things move or keep them from moving, depending on the frame of reference.

IV. Force, Motion and Mechanical Energy A. Relative Motion

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. An object's position can be described relative to another object (above, below, left of, right of, behind, or in front).	a. describe the position of an object relative to another object (1.8; 1.10)	• Describe the position of a student's desk in relation to the teacher's desk or another student's desk.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness*
2. An object's motion can be described in terms of another object (e.g., faster, slower) and how its position changes over time.	a. compare one object's position and motion relative to another object (1.6; 3.2; 3.3)	• Describe an object's motion and position (in 5-second intervals) relative to a fixed point and relative to another moving object.

IV. Force, Motion and Mechanical Energy B. Types and Properties of Forces and Motion

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Forces explain many kinds of motion (e.g., stopping, starting falling, straight, zigzag, circular, vibrational).	a. express ideas on the type of motion an object is undergoing (2.1; 2.4)	• Observe and describe the motion of a feather, guitar string, merry-go-round, swing, etc.
2. Force is any push or pull exerted by one object on another.	a. identify the forces on a moving object and predict the direction it will go (1.6)	• Describe the forces acting on a ball thrown straight up. • Describe the forces acting on a moving toy and predict the movement it might take.
3. Weight is a measurement of the attraction of gravity on a mass. Mass is the amount of matter of an object.	a. use the appropriate tools to weigh an object then find its mass (1.4; 1.6; 3.3)	• Use a scale to weigh an apple; use a balance to mass the same apple; compare numbers. Repeat with other objects.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
4. Forces can be mechanical, gravitational, magnetic, or electrostatic.	a. demonstrate the force of gravity by using a scale (2.1; 3.7; 4.1)	• Prepare a demonstration using a scale to measure the effects of gravity on common objects.
	b. design and conduct inquires to study the effects of an electrostatic force on the motion of an object (1.3; 1.6)	• Use a comb and pieces of paper to demonstrate electrostatic force.
	c. demonstrate and investigate magnetic force fields (1.1; 1.2; 1.3; 1.4; 1.6; 2.1; 2.3; 3.2)	• Use a bar magnet and iron filings in a plastic bag to demonstrate a force field. Sketch the field lines.

SCIENCE K–4

IV. Force, Motion and Mechanical Energy C. Interactions of Forces and Motions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Magnets attract and repel each other and certain kinds of metals.	a. work as individuals and collaborate with others to identify the materials that are attracted to a magnet (3.2; 4.6,)	• Observe the effect of one magnet on another and on other objects.
2. The movement of an object depends on the force applied and how much mass it has.	a. identify and analyze how much force is needed to move a variety of objects (1.6; 2.4; 3.3; 3.5; 4.1)	• Using various objects in the classroom, determine which are easier to move.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
3. An unbalanced force causes an object to change speed or direction. The magnitude of the change in speed or direction depends on the amount of force applied and the mass of the object.	a. evaluate data and describe the relationship of the amount of force applied to an object, the mass of the object, and the amount of change in the object's motion (1.4; 1.6; 2.5; 3.1; 4.1)	• Explore how objects of various mass travel different distances down an inclined plane. Predict where a new object (mass) will stop based on the collected data. • Analyze the forces on a thrown ball to formulate strategies to predict the direction and distance of the ball.
4. Simple machines are used to change the direction of an applied force and provide the mechanical advantage needed to move objects.	a. analyze and evaluate the way a simple machine increases the applied force (1.1; 1.2; 1.3; 1.6; 2.1; 2.5; 4.1)	• Describe how forces work in common simple machines (e.g., seesaws, crowbars, slides). • Discuss the mechanical forces used in everyday tasks (e.g., riding a bike, swinging in a swing) and identify the forces and motions involved and how they change.

SCIENCE 5–8

IV. Force, Motion and Mechanical Energy A. Relative Motion

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The motion of an object can be described as a change in position, direction, and speed.	a. use appropriate technologies to measure and compute the direction and magnitude of the forces causing the motions of common activities (1.1; 1.3; 1.4; 3.5)	• Describe the position, direction, and speed of a person in an elevator with respect to someone else in the elevator and with respect to someone on one floor of the building.
2. The motion of an object can be represented graphically in terms of direction over time, speed over time, or position over time.	a. organize data concerning the direction and position of a moving object with respect to time in graphical form (1.1; 1.2; 1.4; 1.8; 3.1; 3.5)	• Determine the speeds of objects (e.g., students running, walking, riding a bike) using measurements of distance and time. Compare the results both numerically and graphically.
3. Acceleration occurs when an object speeds up, slows down, or changes direction.	a. explain how an object's acceleration is affected by outside forces and its mass (3.1; 3.3; 4.1)	• Describe the acceleration of a race car as it runs the race course. • Explain, in terms of outside forces, how an object may change its direction or acceleration.

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IV. Force, Motion and Mechanical Energy B. Types and Properties of Forces and Motion

By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The overall effect of many forces acting on an object at the same time is called net force. The size and direction of this net force determines the change in motion of an object.	a. use technologies to determine the direction of acceleration and the net force for an object moving in a circle (1.3; 1.4; 1.6; 1.10; 4.1)	• Define and discuss the forces and acceleration involved when an object changes direction. • Identify the forces involved and determine the net force of a person sitting in a chair. Predict what would happen if the forces were changed.
2. Whenever an object exerts a force on another, an equal but opposite force is exerted back on it.	a. recognize and define the forces necessary for an object to move or be in equilibrium (1.4; 1.7; 2.1; 3.5; 3.7; 4.1)	• Using a model airplane, explain forces that allow it to fly.
3. Every object exerts a force on every other object. Its magnitude depends on the masses of the objects and the distance between them.	a. compare and describe the gravitational force between two objects (1.4; 1.7; 2.1; 3.1; 4.1)	• Explain, in terms of the forces involved, why a satellite orbits Earth. • Compare the gravitational force of one object to another that has a mass 100 times greater.

SCIENCE 5–8

IV. Force, Motion and Mechanical Energy C. Interactions of Forces and Motions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Mechanical energy comes from the motion (kinetic energy) and/or position (potential energy) of an object.	a. interpret and explain the relationship among kinetic energy, potential energy, and mechanical advantage (1.6; 1.8; 2.1; 2.3; 2.5; 4.1)	• Determine the amount of mechanical energy necessary to turn a flywheel of a car's engine. • Explain and demonstrate the types of energy, changes in motion, and mechanical advantage involved in shooting an arrow.
	b. analyze the changes in kinetic and potential energy in common activities (1.5; 4.1; 4.10)	• Determine the amount of potential energy in a water tower.
2. The work done on an object depends on both the applied force and the distance an object moves.	a. determine the amount of work done when an object is moved or when a task is performed (1.5; 4.1; 4.10)	• Compare the amount of work done in mechanical or electrical devices.
3. Simple machines can be used to change the force on an object, its speed, or its direction of movement.	a. explain and demonstrate how common tools are simple machines and discuss the forces and motions involved (1.1; 1.6; 1.10; 3.1; 3.6; 4.1)	• Give examples of simple machines found in the human body and explain the mechanical advantage they provide. • Compare the masses of several objects and the distances from the fulcrum of a balanced lever. Predict the unknown mass of an object hanging on the fulcrum. • Determine the amount of force necessary to lift objects with different types of pulleys.

IV. Force, Motion and Mechanical Energy A. Relative Motion

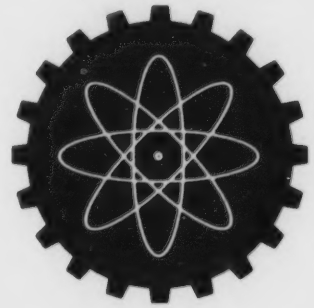
What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Motion can be described in terms of velocity and acceleration and be represented by equations and vectors.	a. represent and analyze motion both quantitatively and graphically using velocity and acceleration (1.8; 2.4; 3.5; 4.1)	• Determine the effects of wind on the flight of a plane and communicate those conditions with vector diagrams. • Describe the flight path of an arrow in terms of its acceleration.

IV. Force, Motion and Mechanical Energy B. Types and Properties of Forces and Motion

By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The acceleration of an object is related to its mass and the force acting on it.	a. analyze information from inquires to interpret the effects of forces on velocity, acceleration, and equilibrium of an object (1.2; 1.4; 1.7; 3.5; 3.7; 4.1)	• Determine the weight of an object in Newtons. • Analyze the types of forces and motions of several amusement park rides for possible structural problem.
2. The action of all forces can be explained by Newton's Laws of Motion that are used to predict changes in linear and/or rotational motion.	a. evaluate information to describe how Newton's Laws of Motion are used to describe moving objects (1.7; 2.4; 3.4)	• Conduct measurements and calculate the retarding force of the brakes of a car, train, truck, etc.
3. Moving electric charges produce magnetic fields that exert a magnetic force on other objects; moving magnets can produce electric forces.	a. select and apply appropriate strategies to investigate the relationship between a magnetic force and an electric current and devise a practical application using this relationship (1.6; 1.10)	• Design, construct, and demonstrate an electromagnet capable of lifting several Newtons. • Examine the process of induced polarization. Create models to account for what is observed. • Investigate the relationship between magnetic force and electric current. • Devise an experiment to generate an electric current using a wire and a magnet.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. A force acting on an object, moving it through a distance, can change its kinetic energy, potential energy, or both.	a. describe the forces acting on a moving object that changes the object's kinetic and potential energy (1.6; 1.10; 3.5; 4.6)	• Analyze and describe the changes in kinetic and potential energy that take place when a basketball player dribbles or shoots the ball.
2. The ratio of output work to input energy is the efficiency of a machine or process and is always less than 100%. Power is the rate at which work is done.	a. analyze and describe the relationship among work, power, and efficiency (1.6; 1.10; 2.4; 3.4; 4.1)	• Collect data and organize information to analyze the work, power, and efficiency of a refrigerator.
3. The Law of Conservation of Momentum can be used to predict the outcome of collisions.	a. evaluate information to describe and discuss the result of a collision between two or more moving objects (1.6; 2.3; 3.8)	• Predict and discuss the results of the collisions of a cue ball with one or more billiard balls.

V. UNIVERSE
(SHOW-ME STANDARDS, SCIENCE 6)



A. Characteristics of the Universe
B. Motions of the Universe
C. Tools of Space Exploration

K-12 Content Overview:

Students today are growing up in a world of space travel and exciting new discoveries. Studying the universe helps students understand both the nature of the universe and the important contributions space exploration has made to our understanding of the universe and humankind.

The universe contains billions of galaxies, each of which contains billions of stars of various types. Our solar system, located near the edge of one galaxy, contains a very important star (the sun), planets, moons, asteroids, and comets.

By observing the sky on a regular basis, elementary students learn to identify changes and patterns. Observations of these changes and patterns help children understand and describe what is happening in the universe. Knowledge of the universe and the Earth's position in it provides students with a sense of time and place. The Earth's location and motion in relation to that of the sun and moon cause significant changes in the Earth's physical environment. Because direct experimentation is not possible for testing most concepts related to the universe, students must rely on data collected through technology, which, in turn, requires students to develop sequential thinking skills and the ability to follow logical multisteps to draw conclusions and make predictions.

By the middle level, students identify the characteristics of stars, their composition and distance. Current models of the universe used by high school students are based on mathematical and computer simulations.

Patterns, positions and distances of celestial objects are observed and measured with the use of telescopes and satellite images. The impact of technology on data gathering, prediction, and knowledge challenges students to follow the multistep logic necessary for understanding .

V. Universe A. Characteristics of the Universe

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Earth is not alone in the universe. Most of the objects in the universe are separated by enormous distances.	a. present ideas and opinions about the relationship of the sun and moon to Earth and Earth's position in the universe (2.1) b. describe the major components of our solar system (1.3; 1.8)	• Draw a picture of the relative positions of the Earth, moon, and sun. • Use scaled objects at different distances to model the solar system and show the distances between and sizes of the planets.
2. The sun, moon, and stars have recurring patterns.	a. evaluate information about the sun and moon and share to determine patterns, changes, and relationships (1.2; 1.6; 3.5)	• Identify patterns and changes in the sun, moon, and stars.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
3. Constellations are patterns of stars.	a. identify the major constellations and determine the seasonal changes in patterns (4.6) b. research and report on the legends of major constellations (1.4; 1.8; 2.1)	• Observe the night sky over an extended period of time, keeping a record or chart of the observations to identify the major constellations. • Script a play about the major constellations based on legend.
4. Earth is in our solar system and has unique properties.	a. compare and contrast Earth's properties to other planets in our solar system (1.2; 1.6)	• Identify some characteristics of Earth that allow it to support life.
5. Earth rotates on a tilted axis and revolves around the sun. This combination causes changes in the amount of sunlight reaching the Earth's surface and makes our seasons.	a. explain how Earth's movements and tilt cause seasons (1.4; 2.1; 2.7)	• Model a demonstration of the tilt of Earth's axis in relation to the place of the orbit around the sun and use it to explain seasons at different places on the Earth.

V. Universe B. Motions of the Universe

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Objects in the sky move.	a. use senses to gather information about the day sky through regular observations (1.3; 1.6; 2.3)	• Observe and measure the shadow of a specific object at different times of the day, and determine the direction of the shadow points in relation to the position of the sun.
2. Earth makes a full rotation on its axis every 24 hours that causes the day/night cycle.	a. explain the relationship of the rotation of Earth and the day/night cycle (1.2; 1.7; 2.3; 3.5; 4.1)	• Use a ball and a light source to demonstrate the cycle of night and day and the rotation of Earth.
3. Patterns of movement of some objects in the sky are cyclic.	a. discover and evaluate patterns in the sky (1.6; 3.5; 4.1)	• Record observations of the day and night skies over an extended period of time and identify patterns of movement.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
4. The motion and positions of objects in the solar system are observable phenomena that can be explained.	a. evaluate information about the motion and position of Earth, moon, and sun to determine the patterns that give us our day, month, year, moon phases, and eclipses (1.6)	• Demonstrate the positions and motions of the sun, moon, and Earth to explain moon phases, solar eclipse, and moon eclipse.
5. Recurring predictable movements of the Earth and moon can be used to measure time.	a. explain how time can be based on the movements of Earth in relation to the sun, moon and stars (1.3; 1.6; 1.8; 2.7; 4.6)	• Make a working sundial and explain how it was done. • Construct and use a Big Dipper star clock.
6. Different constellations can be seen in different seasons.	a. explain why certain constellations can be seen only at certain seasons (1.6; 2.4; 3.5; 4.1)	• Illustrate how the Earth's position relative to the sun determines which constellations are visible in different seasons.
7. The sun, moon, stars, and planets appear to move from east to west each day	a. explain the reasons for different time zones (1.2; 3.5; 4.1)	• Chart the times and directions of sunrise and sunset over a 2-month period in two different time zones.

V. Universe C. Tools of Space Exploration

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Special clothing and equipment must be used by people who travel into space.	a. explain the use of different clothing and equipment used by people who travel into space (1.5; 1.6)	• Compare and contrast the clothing and equipment used during early and current space explorations.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Telescopes and satellite imaging allow scientists to observe features and structures of some objects in the sky.	a. identify prominent features of Earth and planets (1.4)	• List obvious features of the moon and Earth from some NASA photographs and satellite images. Name some things that can be learned or predicted from studying these images.
3. Space exploration has provided many benefits to humankind.	a. identify and explain some ways that food, clothing, or machines have changed as a result of the U.S. space program (1.2; 3.6; 4.1; 4.7)	• Investigate the impact that space technology has had on food preservation.

SCIENCE K–4

V. Universe A. Characteristics of the Universe

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The universe is so large that its distances are expressed in special units (i.e., light years, astronomical units).	a. use visual and mathematical aids to determine the approximate locations of stars in the constellations (1.4; 2.2)	• Design and construct a planetarium that models the constellations in the northern hemisphere. • Use scale drawings to determine the distance between Earth and the moon. Explain how these methods can be used to estimate astronomical distances and how linear measurements convert to light years.
	b. create a model in which the same scale is used to depict the distances between objects and calculate the time required to travel a direct path to them from Earth (1.6; 2.1)	• Describe the relative sizes of the planets (as viewed from Earth) and their distances from the sun.
	c. interpret and evaluate information related to distances from our solar system to other points in our galaxy and the universe (1.2; 1.7; 2.7; 3.5; 4.1)	• Use triangulation to determine the distance between specific points on Earth. Explain how this method can be used to estimate astronomical distances.
2. Celestial objects possess both similarities and differences.	a. use a variety of resources to compare and contrast the physical properties of planets (1.8; 3.5; 2.3)	• Use NASA photographs and satellite images to compare the size and surface features of the planets and their moons. • Create an itinerary of a space vacation that describes what will be seen at different stops along the way.
3. Our solar system is part of the Milky Way Galaxy, one of many galaxies in the universe.	a. use a variety of visual aids to locate the position of the solar system in the Milky Way Galaxy (1.5; 1.6; 2.2; 2.3; 4.1)	• Use photographs to approximate the location of the solar system in the Milky Way Galaxy.

SCIENCE 5–8

V. Universe B. Motions of the Universe

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The force of gravity determines the orbital patterns of celestial objects.	a. conduct an investigation that demonstrates planetary orbits and apply the processes and knowledge learned to patterns within the solar system (1.3; 1.6; 3.5)	• Use ball bearings with different strengths of magnets to simulate planetary orbit patterns.
2. Earth is a moving planet that has unique features.	a. use a variety of methods, forms, and technologies to describe Earth (1.4; 2.7; 3.5; 4.1)	• Analyze satellite data or perform sun angle measurements to test the assumption that Earth is spherical and rotates on its axis.
3. Earth rotates on tilted axis as it revolves around the sun causing sunlight to hit at different angles. The revolution and tilt produce seasonal variations in weather and climates.	a. evaluate how revolution, rotation, and tilt of the Earth influences the amount of sunlight that reaches the surface (1.7; 1.8)	• Build models to demonstrate and predict the seasons in different hemispheres of Earth at a given time. Chart this information and compare the results to weather patterns in Missouri throughout the year.
4. Moon phases and eclipses result from the angle from which we view the moon.	a. explain such phenomena as lunar and solar eclipses and moon phases (1.6; 2.4; 2.5)	• Monitor the position and phases of the moon for a complete cycle, and construct a sun/moon/Earth model to explain the observations.
5. Nine planets, their moons, comets, asteroids, and meteorites orbit the sun.	a. explain how planetary orbits are affected by gravitational forces of other planets and the sun (1.5; 1.7; 3.3; 4.6)	• Use scale models of the solar system to demonstrate the relative sizes of the planets and their moons, as well as their distances from the sun, and the primary orbits.

V. Universe C. Tools of Space Exploration

By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. A variety of technological tools are used to provide information concerning the physical properties and conditions of the solar system.	a. discuss how information received from space probes has either confirmed or modified scientific theories concerning conditions on other planets (1.7; 2.4; 3.1; 3.5; 4.1)	• Select a space probe mission and research what type of information these robotic explorers have provided about the solar system. Discuss how this information has either confirmed or modified scientific theories about other planets.

SCIENCE 5–8

V. Universe C. Tools of Space Exploration

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
2. Most information about the universe comes from the electromagnetic spectrum.	a. use an illustration of the electromagnetic spectrum to describe the relationship between wavelength, energy, and frequency (1.4; 2.7; 3.5; 4.1)	• Use full electromagnetic photograph to view objects in the sky to see a wide range of features and information.
3. Research associated with space exploration has resulted in technological advances that have affected the quality of life.	a. identify common products that have been developed as a result of research associated with space exploration	• Collaboratively make a list of everyday items that are spin-offs from the space program.

V. Universe A. Characteristics of the Solar System

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The current model of the universe was developed from evidence about its content and theoretical assumptions based upon mathematical and computer-simulated models.	a. present organized arguments and opinions about the various scientific theories on the formation of the universe (2.4)	• By inflating a balloon which is covered with dots, demonstrate that from any perspective the expansion of the universe results in spreading points. Support this expanding universe idea with actual photographs and data from NASA. • Compare Earth's chemical composition, size, and position in the solar system to those of other planets. Based on this comparison, discuss and debate the possibility of the existence of life on other planets.
2. Stars appear to go through a cycle of birth, development, and death.	a. use information about a star's characteristics to determine its age (1.6; 3.5)	• Explain how scientists have used information about a star's size, composition, mass, surface features, and temperature to develop models of stellar evolution.
3. Because of the vast distances between objects in the universe, light may take billions of years to reach Earth.	a. explain the different units used to measure distances by astronomers and explain why they use them.	• Calculate the length of time it takes for light to travel from the sun to Mars.

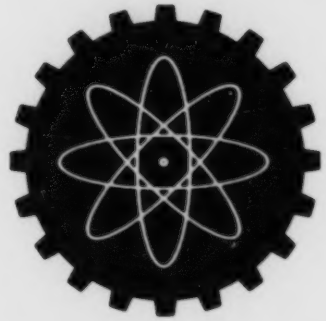
V. Universe B. Motions of the Universe

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Newton's conception of the universe established the idea that the laws which apply to processes that occur on the Earth also apply to the universe.	a. evaluate information and products to determine the relationship of Newton's Laws in space and on Earth (1.3; 1.5; 1.7)	• Examine NASA simulations to gather data that demonstrate Newton's Laws. • View a "Star Wars" movie and identify applications and misapplications of Newton's Laws.
2. Gravitational laws explain planetary motion and tides.	a. develop a logical description of how gravitational laws explain the movement of planets and tides (1.6; 2.4; 3.5; 4.1)	• Apply the laws of gravitation to explain why planets closer to the sun must move faster and planets farther from the sun move slower.

V. Universe C. Tools of Space Exploration

By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Space exploration has expanded our knowledge of the universe and advanced the technological sophistication of our society.	a. identify and explain ways society has benefited from the technologies developed through space exploration (1.1; 1.2; 1.4; 1.7; 1.9; 1.10; 2.7; 2.2; 3.5; 4.1; 4.6)	• Research the history of the space program and explain the technologies used in getting people and equipment into space.
	b. evaluate the economic impact of the space program (1.1; 1.2; 1.4; 1.5; 1.7; 1.8; 2.1; 2.3; 3.5; 4.1; 4.6)	• Research how the development of new materials, computers, flight designs, etc, for space exploration has benefited society economically.

VI. EARTH SYSTEMS
(SHOW-ME STANDARDS, SCIENCE 5)



A. Physical Systems
B. Processes of Systems

K-12 Content Overview:

Knowledge of the processes and physical nature of Earth provides students with a picture of Earth's past, present, and future. The physical laws that have governed the entire universe in the past are the same as those that govern material interactions today. Earth's physical systems, comprised of subsystems (biosphere, atmosphere, hydrosphere, and lithophere) , are continuously interacting with one another. Changes in each of the subsystems impact Earth's physical and biological characteristics.

The processes on Earth, such as the movement of plates and the flow of air and water, are driven by heat energy from within the Earth and by heat generated when sunlight strikes the atmosphere and surface of Earth. Interactions between heat and other forms of energy with matter on Earth shape its surface, determine its climate, affect its atmosphere, and set the stage for life. Earth provides humans with the resources they need to sustain life and to advance technologically; however, as people use these resources, they have also altered Earth systems. Questions of environmental policy should be pursued when students become aware of these related issues.

VI. Earth Systems A. Physical Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Water reaches Earth in different forms (snow, hail, rain, fog, etc.).	a. conduct research to develop and evaluate information and ideas about how water in various forms reaches Earth (1.2; 1.6; 3.5)	• Use a globe to identify different areas that would have lots of or very little rain, snow, fog, etc.
2. Earth's natural resources are limited.	a. conduct research to develop and evaluate information on the use and abuse of Earth's natural resources (1.2; 1.9)	• Construct posters that promote responsible use of water or trees.
3. Earth's surface is composed of rocks, soils, water, and living organisms. Differences in these components can be used to classify them.	a. apply knowledge and skills to classify a variety of rocks or soil (1.10; 3.5)	• Collect a variety of rocks or soil and classify them according to one type of physical property.
4. The atmosphere has physical properties that are measurable and predictable.	a. conduct research to develop and evaluate information about the atmosphere; plan and make a written, oral, and visual presentation of the patterns of change over a period of time (1.2; 1.4; 1.8; 2.1)	• Keep a journal of temperatures and weather conditions for a month or two. Identify patterns • Compare the seasonal changes and describe how humans have adapted to them.

VI. Earth Systems A. Physical Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
5. Fossils provide evidence of plants and animals that lived long ago and the environment in which they lived.	a. plan and make a written, oral, and visual presentation about the natural history of our state based on evidence of fossils found in Missouri (1.3; 1.8; 1.9; 2.1)	• Compare and contrast the Missouri environment of today to that of long ago through fossil evidence. • Compare the similarities and differences between fossils and living organisms. Ask reasonable questions about those comparisons.
6. Water is a valuable natural resource essential to all life.	a. exchange information and ideas with others about water conservation and the essential need for water by all living things while recognizing different points of view (1.4; 1.8; 2.3; 2.7)	• Survey family and friends to see how many ways they use water. Compare findings with classmates and classify essential uses.
7. Rocks, minerals, and soil have physical characteristics by which they can be classified.	a. classify rocks, minerals, and soils according to their physical characteristics (1.6; 1.8)	• Classify a given group of rocks according to color.
8. Soil composition varies from location to location and affects the type of plants that grow in that location.	a. use technological tools and other resources to locate, select and organize information from simple investigations to determine which plants grow best under various conditions in a variety of locations (1.4; 1.6; 3.5)	• Create and conduct simple investigations to determine what plants will grow best in different kinds of soil.

VI. Earth Systems B. Processes of Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Water is stored all over Earth.	a. discover and evaluate patterns and relationships in information to predict and identify areas that store water (1.3; 1.6; 2.4; 3.5)	• Identify areas of Missouri that store water above and below ground.
2. Rocks change over time by weathering.	a. conduct research to develop and evaluate information to show how rocks change over time by weathering (1.2; 1.6; 1.8; 2.4; 3.5; 4.1)	• Observe and describe signs of weathering on a brick building, statue, bridge, cliff, etc.
3. Earth's rotation causes a day and night cycle.	a. identify the apparent position of the sun throughout the day (1.3; 1.6; 2.3; 3.1; 4.6)	• Using sticks in the ground, mark the position of the shadows during a sunny day. Describe what is observed.
4. Seasons and changes in weather affect human and animal activity and plant growth.	a. apply the knowledge and skills learned from weather observation and investigations to study the effect on human and animal activity and plant growth (1.3; 1.6; 1.10; 3.2; 3.3)	• Compare the different weather patterns in northern and southern parts of the United States. Discuss how these patterns influence plant growth and human activity in those states.
5. The surface of Earth changes slowly (e.g., erosion, weathering) or quickly (e.g., earthquakes, floods, rock/mud slides, volcanic activity).	a. present perceptions and ideas on ways the surface of Earth changes slowly or quickly (2.4; 4.1)	• Choose a natural disturbance (flood, heat wave, snow, ice storm) and identify the changes it caused and how it affected plants, animals, and humans.

VI. Earth Systems B. Processes of Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
6. Water condenses, evaporates, and exists as a gas liquid or solid on Earth and in the air.	a. develop strategies for predicting and addressing the effect of temperature or wind on evaporation and condensation (2.4; 3.2; 3.3)	• Conduct investigations to determine the effect of temperature or wind on evaporation and condensation.
7. Earth's surface features are continually changing.	a. select and apply problem-solving strategies using prior knowledge and experiences to show how and where Earth's surface is continually changing (1.10; 3.2; 3.3)	• Use globes and maps to identify major geological features. Compare Missouri's features to those in other states. • Choose a local area that has undergone changes due to erosion, wind, or plant/animal/human activity. Identify these changes as slow or rapid.

VI. Earth Systems A. Physical Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The atmosphere is composed of a chemical mixture of gases, water vapor, and minute particles.	a. use appropriate technology and other resources to select and organize information about atmospheric properties (1.4)	• Given data on variations of atmospheric composition, explain changes in the atmosphere over a period of time and predict possible future scenarios.
2. Properties of the atmosphere are observed and measured to predict weather changes.	a discover and evaluate patterns and relationships in the properties of the atmosphere and their structure; develop strategies to predict weather changes (1.7; 3.2)	• Use appropriate technology and weather maps to record weather data for 2 months. Identify any patterns and predict the weather for a week.
3. Rocks and minerals can be classified by their chemical and physical properties.	a. conduct research using chemical testing and evaluate the information to classify a variety of rocks and minerals (1.2; 1.6; 3.5)	• Group rocks and minerals according to properties determined by chemical tests.
4. Surface and subsurface rock and mineral deposits lead to the determination of age, origin, and events in Earth's history.	a. use appropriate technology and other resources to locate, select, and organize information to determine relative age of mineral, rock, and soil samples or associated events that may have occurred (1.4; 1.6; 1.10)	• Research how rock composition, layering, and physical structure reflect the geologic history of an area.
5. Formation of layers of sedimentary rock and their associated fossils confirm the long history of Earth and its changing lifeforms.	a. construct models and geological profiles to demonstrate the age relationship of sedimentary rock layers (1.8)	• Analyze information from field research of a nearby road cut, stream bank, or ditch to interpret the sequence of rock layering and relative age.
6. Surface and subsurface water replenish each other. Human activity and natural events can affect the quality of the supply.	a. organize data, information, and ideas about human activity and natural events that affect the quality of water supplies for analysis and presentation (1.8)	• Research the impact of human activity on the Missouri and Mississippi Rivers. • Determine the amount of surface water stored in Missouri. How much water do Missourians use in 1 day? Relate the two.

VI. Earth Systems A. Physical Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
7. There is economic value in Missouri resources, both above and below ground.	a. reason inductively about Missouri's mineral deposits and their relationship to the economy and deductively about environmental concerns—past, present, and future (3.5)	• Identify major resources in Missouri and their annual value from products (lead, iron, limestone, etc.). • Compare and contrast present day maps, land images, and aerial photographs of Missouri to those of the past. Identify any changes that have occurred in the topography of Missouri and investigate reasons for the change.
8. Earth has three distinct physical spheres: atmosphere, hydrosphere, and lithosphere. Each has different compositions yet interfaces with each other.	a. collaborate with others in developing and clarifying perspectives by applying knowledge, measurement, and concepts of the hydrosphere, lithosphere, and atmosphere (2.4; 4.6)	• Describe how soils influence the agricultural productivity and economy of the area. • Construct a closed system terrarium with standing water and multiple lifeforms and make ongoing observations of the cycling of water and/or other substances.
9. The benefit of resources from Earth's physical spheres can be reduced by deliberate or inadvertent misuse or destruction.	a. using appropriate technology, identify, analyze, and evaluate causes of pollution and its effect on an area; use this information to create a model demonstrating the complexity of pollution (1.4; 1.6; 1.8; 2.4; 3.5; 4.1)	• Use maps, satellite imagery, instrumentation, etc., to locate possible sources of atmospheric pollution. Compare sources with meteorological data to locate possible origin of local contamination.

VI. Earth Systems B. Processes of Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The water cycle is driven by energy transfer processes, such as convection and radiation, and is constantly changing the location and phase of water.	a. exchange information, questions, and ideas with others to discuss the effects of energy transfer on the water cycle (2.3)	• Construct a model to demonstrate the processes of the water cycle. • Design simple experiments to demonstrate the influence of wind and temperature on the hydrologic cycle.
2. Large bodies of water have a major effect on weather and climate. Ocean currents are caused by differences in temperature and salinity.	a. organize data, information and ideas into useful forms for analysis and summary to predict climatic patterns associated with large bodies of water (1.8)	• Examine maps of ocean currents to trace their origin and flow. Explain the transport of heat energy in these currents.
3. The surface of Earth has changed as a result of dynamic forces originating within the mantle. The physical evidence (faulting, volcanoes, folding of rock, etc.) of these constructive and destructive forces is associated with plate movement.	a. conduct an investigation to develop and evaluate information and ideas concerning the theory of plate tectonics; use landform models and maps to analyze the distribution of global features and geological phenomena such as volcanoes and earthquakes (1.3; 1.8)	• Demonstrate how forces on materials cause wrinkles, folds, and faults. • Plot the location of earthquakes, volcanoes, trenches, and oceanic ridges to identify patterns of evidence for the existence and movement of crustal plates.
4. Properties of soil and the hydrology of surface and groundwater have physical and cultural impact standpoints.	a. conduct research to develop and evaluate information and ideas of the human impact on water resources (1.2) b. design and conduct field or laboratory investigations to study types of soil; recognize how the different types of soil lead to differences in drainage, percolation for septic systems, and groundwater quality (1.3; 1.6; 3.1)	• Identify a source of contamination using a model designed to simulate groundwater testing methods and discuss challenges to locating and cleaning underground contamination. • Identify a local watershed and determine the factors that influence the replenishment of the groundwater supply.
5. Incoming solar radiation and the hydrologic cycle create patterns of weather and climate.	a. design and conduct investigations to study the effects of solar radiation, tilt of the Earth's axis, and the water cycle on patterns of weather and the climate on Earth (1.3)	• Design and construct an experiment using a sphere, light source, and measurement tools to collect data on solar radiation and weather.

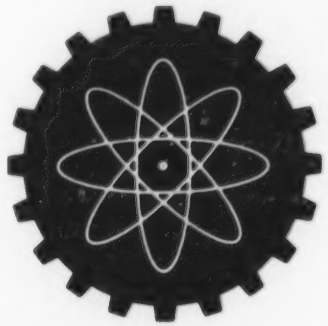
VI. Earth Systems A. Physical Systems

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Variations in the physical conditions and chemical composition of soil are a result of the type of rock from which it came, climate, the process by which it was deposited, and biological activities.	a. discover and evaluate the patterns and relationships of the soil to the origin of the local rock type, climate, processes of deposition, and biological activity (1.6)	• Relate how composition and physical structure of soil reflect local geology by comparing soil maps to geological maps. What would you find in the northern, glaciated portion of Missouri?
2. Changes in the atmosphere can be caused by natural or human activities.	a. identify and describe the scope of the impact of human activity on the atmosphere (3.1)	• Research and report the impact human activities have on the atmosphere (car exhaust/breathing problems, industrial emissions/acid rain, etc.).
3. Variations in composition of the atmosphere and hydrosphere caused by natural activities affect all life on Earth.	a. investigate information on several natural disasters and predict possible reactions of plants, animals, and humans (1.3; 1.6; 1.8; 2.3; 3.5)	• Study the effects of a recent volcano eruption on the atmosphere. Develop a timeline of the dust flow around Earth and predict possible reactions of plant, animal and human behavior.
	b. use appropriate technology and other resources to locate, select, and organize information about natural disasters and their effect; develop strategies to predict occurrences and/or reduce or solve the resulting problems (1.4; 3.2)	• Using library and Internet sources, identify and research a natural event that has affected the atmosphere and/or hydrosphere. Participate in a discussion on the Internet addressing possible actions that might reduce the effect.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Elements cycle through the atmosphere, hydrosphere, lithosphere, and biosphere. The movement of matter through the spheres is driven by Earth's internal and external sources of energy.	a. conduct research to develop and evaluate information on the movement of matter through a model ecosystem (1.2)	• Conduct an ongoing investigation, accompanied by research, utilizing a worm farm, isopod colony, or other habitat to gather information on movement of matter through systems.
2. Crustal plate movement affects Earth's topography and provides evidence of a geologic time scale.	a. using a variety of models and other resources, design and conduct an investigation to study Earth's energy sources; apply the processes and knowledge learned to understanding changes in Earth's surface (1.3; 1.6; 3.2; 3.3; 4.1) b. use appropriate technoloy to locate, select, and organize information related to a plate movement; conduct research using a simulation of that event and evaluate the information (1.2; 1.4) c. identify the theories associated with major geological events and present the information in the form of a time line (3.1)	• Construct a model of convection currents that involves collecting quantitative data. • Study the p-waves and s-waves of a computer-simulated earthquake to locate the epicenter. • Construct a diagram, 3-D model, or AV simulation that shows the position of crustal plates at different times in Earth's history. Establish links that support these crustal positions.
3. Circulation of air and water around Earth, driven by radiation energy from the sun, causes weather phenomena and regional climate.	a. discover and evaluate the patterns and relationships in the circulation of air and water around Earth, how they are driven by radiation energy from the sun, and how this causes weather phenomena and regional climates (1.6)	• Construct climatograms and examine world and regional maps showing climatic zones to compare the effect of different variables on the climate of an area. Identify areas that would be expected to have climates similar to and different from Missouri. • Investigate the differential heating rates of soil and water and collect and graphically represent data for inland vs. coastal area.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
4. Science technology has enhanced our ability to detect atmospheric changes resulting from interactions of Earth's systems.	a. use appropriate technology to locate and select patterns of global and local weather and climate changes resulting from interactions of Earth's systems (1.4)	• Explore how technology (weather satellites, Doppler radar, aerial photographs, Landsat imagery) has enhanced our understanding of atmospheric changes and land use.

VII. LIVING SYSTEMS
(SHOW-ME STANDARDS, SCIENCE 3)



- A. Structures/Function/Characteristics
- B. Life Processes
- C. Diversity
- D. Reproduction/Heredity
- E. Adaptation/Evolution

K-12 Content Overview:

Observation and classification of living things began with the need of the earliest humans to survive. Human curiosity and desire to organize have led to systems that classify the complex diversity of life based on knowledge of external features, behaviors, internal structures, and molecular evidence. Understanding and appreciating the diversity of life comes from students' ability to see the patterns of similarity and differences that permeate the living world. The living environment consists of millions (perhaps tens of millions) of different types of organisms, all of which carry out the same basic functions that have maintained life for millions of years. The information required to carry out the life functions is encoded in chemicals in the nuclei of cells and is passed from generation to generation. A complex interplay between variations in the genetic code and environmental factors results, over time, in changes in living organisms.

The challenge for educators is to capitalize on the interest that students have in living things while moving them gradually toward ideas that make sense out of nature. Familiarity with the phenomena should precede their explanation, and attention to the concrete object should precede abstract theory. (The "Functions and Interrelationships of Systems" strand within the Health/Physical Education framework contains content related to body systems.)

VII. Living Systems A. Structure/Function/Characteristics

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Observable characteristics of living organisms can be used to sort and group them.	a. sort common objects based on color and/or shape and use this skill to sort common organisms (1.5)	• Observe and compare similarities and differences in mature and immature organisms (dogs/puppies, frogs/tadpoles, trees/saplings).
	b. discover and evaluate patterns and relationships of living organisms (1.6)	• Sort common organisms based on one or two physical characteristics such as color, number of legs.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Organisms differ in structure and function and have characteristics that help them survive and reproduce in different environments.	a. interpret and explain patterns and relationships of the animals' structure and systems based on data given about different animals (1.6; 1.7; 1.8; 2.2)	• Examine crickets, mice, birds, etc., and explain how different physical structures help them survive.
3. Plants and animals are alive and have characteristics that make them different from nonliving matter.	a. identify characteristics that determine whether an object or material is living or nonliving and apply that knowledge to unknown samples (1.2; 1.3; 1.6)	• Describe how a tree and a turtle differ from a rock. List these characteristics and identify the similarities and differences that exist.

VII. Living Systems B. Life Processes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Organisms go through life cycles.	a. observe and record the phases in the life cycle of various organisms and compare the differences between species (1.3; 1.6; 2.4)	• Discuss the human life cycle and generate some reasonable questions about differences in various developmental stages—newborn, child, adolescent, adult, elderly. • Create an illustration that depicts physical changes in an animal from birth to maturity.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Most organisms require a variety of materials including food, water, air, and a suitable environment for survival. Animals obtain energy and nutrients from plants or other animals.	a. conduct investigations to gather data, information, and ideas relating to the energy and nutrients organisms need from their environment in order to survive (1.3) b. summarize the effect of various conditions on plant and animal survival tactics (2.1; 2.3)	• Compare a human's energy and material needs for growth to the same needs for other organisms. • Explore a simple, natural system (e.g., classroom aquarium or outdoor habitat) and generate questions about the transfer of energy and use of nutrients.
3. Organisms are composed of parts that work together and exhibit behaviors that ensure the survival of the whole organism.	a. discover and evaluate patterns and relationships between the parts of organisms that work together and the behaviors that ensure the survival of the whole organism (1.7; 1.8)	• Observe and record the behaviors of plants under a variety of conditions (e.g., changes in light, water, composition of soil, and use of fertilizers) and relate the observations to the plants' requirements for survival.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Organisms can be grouped by specific structures.	a. group organisms according to similar specific structures (1.6)	• Group students by hair color, eye color, etc.
	b. compare living things using one or more structure attributes (1.6)	• Distinguish between types of plants by comparing size, leaves, shape, blossoms, etc. • Sort pictures of animals by physical traits such as: exoskeletons, shells, hair, feathers, scales.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These sample activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Some characteristics of organisms are inherited and some are acquired as a result of interaction with the environment.	a. identify and consider a variety of viewpoints when interpreting whether characteristics are inherited or acquired (2.3; 3.4)	• Investigate and describe the habitats of local organisms. Identify physical structures and behaviors that enable them to survive in their environment.

VII. Living Systems D. Reproduction/Heredity

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Most offspring are similar but not exactly like their parents.	a. identify and discuss the similarities and differences between parents and their offspring (1.6)	• Observe parents and offspring of various species and draw reasonable conclusions about the inheritance of traits such as body shape, coloration, and behavior.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Organisms resemble their parents because they inherit physical characteristics from them. Organisms with two parents inherit characteristics of both.	a. organize physical characteristics of offspring and parents into useful forms for communicating visual clarity and interpret patterns and sources of inheritance (1.6; 3.2)	• Chart and interpret data about inherited characteristics from an actual or hypothetical human biological family. Identify similarities and differences.
3. All types of living organisms have offspring, and the similarities between parents and their offspring become more apparent as the offspring mature.	a. design and conduct investigations to observe and compare similarities and differences between offspring and their parents (1.3; 1.8)	• Observe and compare similarities and differences between mature birds/nestling, butterflies/caterpillars, etc.
4. The phases in the life cycle of all living organisms are predictable, but differ from species to species.	a. design and conduct investigations to observe and record the life cycles of organisms (1.3; 4.6)	• Observe and record the life cycles of an insect, a frog, and a dandelion. Compare the differences.

VII. Living Systems E. Adaptation/Evolution

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Organisms have parts that enable them to live and survive in the world.	a. organize data, information, and ideas about how body parts enable the organism to live and survive (1.8)	• Identify and discuss the functions of arms, legs, mouth, eyes, etc., in seeking and consuming food. • Identify the functions of the various plant structures in growth and development. • Discuss and compare the functions of fins, wings and legs for animal movement.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Organisms of the same species can have variations that provide an advantage in survival and reproducing.	a. design and conduct investigations to observe and describe variations in organisms and to predict how the variations provide an advantage in survival and reproduction (1.3; 1.7; 3.2)	• Observe and describe variations in a species (e.g., length of bean seeds, height of radishes, leg length in grasshoppers). Predict how variations may affect the ability of the organism to survive.
3. Fossils give evidence that organisms that lived in the past were both similar to and different from present-day organisms.	a. design and conduct investigations to observe similarities and differences in fossils as compared to present day organisms and develop reasonable questions that would account for the differences (1.3; 1.5, 2.2; 4.6)	• Observe and compare the similarities and differences between fossils and common present day organisms.

VII. Living Systems A. Structure/Function/Characteristics

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Organisms can be classified into kingdoms based on similarities and differences.	a. develop and use a classification key that can be used to place common organisms into proper kingdoms (1.1; 2.4; 3.3; 3.7)	• Sort a collection of objects, such as shoes, and create a dichotomous classification key for these objects. • Develop a dichotomous key for the five kingdoms and then use it to sort organisms into the appropriate kingdom.
2. The basic unit of life is the cell. Different cells are specialized to perform various tasks. Cells of similar shape and function are organized into groups.	a. use appropriate technology and other resources to get a visual understanding of the cell as the basic unit of life. Design and conduct investigations to explain why organisms need specialized cells (1.2; 1.3; 1.4; 2.7)	• Examine different types of cells, tissues, and organs and explain why animals need specialized cells (red blood, white blood, muscle, nerve). Do the same for plants (stem, root, leaf).
3. In living systems, from cells to biosphere, components interact within a hierarchy of organization.	a. use a variety of technologies and resources to conduct inquiries into a living system and describe the interaction of components and organisms within any living system (1.3; 1.7)	• Establish an ant farm or bee colony and identify levels or organization.
4. Cells contain a set of structures called organelles that control the various functions of the cell.	a. use appropriate technology to get a visual understanding of organelles; conduct investigations and research on the structure and function of various cell organelles (1.2; 1.4; 2.7)	• Investigate and describe various life processes in unicellular organisms such as amoebae, paramecium, and yeast. • Identify and explain the functions of various organelles (cell wall, cell membrane, nucleus, etc.).

VII. Living Systems B. Life Processes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Energy is needed for living cells to carry out all the processes of life.	a. design and conduct investigations and organize data, information, and ideas about how energy is needed for living cells to carry out all the processes of life (1.2; 1.3; 1.6; 3.1; 4.6)	• Record individual food intake and daily activities for 3 days. Create a table showing the calorie intake and usage that corresponds to daily activities. Participate in class discussions focused on energy requirements of the processes of life.
2. In the process of photosynthesis, green plants convert water and carbon dioxide into energy-rich simple sugars and oxygen.	a. conduct simple experiments with green plants to determine the requirements and products of photosynthesis (1.3; 1.8)	• Measure oxygen bubble production of elodea in water as evidence of photosynthesis.
3. Complex multicellular organisms are interacting systems of cells, tissues, organs, and organ networks that carry out life processes through chemical and physical means.	a. organize information into a model that demonstrates the interaction of systems of cells, tissues, organs, and organ networks in a complex multicellular organism through chemical and physical processes (1.2; 1.5; 2.1; 2.3; 2.4)	• Use models or organisms to learn how organ and organ systems in plants and animals work together for the well-being of the entire organism.

VII. Living Systems C. Diversity

By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. A species is an important biological grouping of organisms whose members have similar structures, normally interbred, and produce fertile offspring.	a. review and revise the definition of a species in order to improve understanding and clarity and apply the definition to sample situations (1.6; 2.2; 2.3; 4.1)	• Determine, using the definition of the word "species," the number of species present in a sample containing numerous kinds of organisms.
2. Each structure in an organism is uniquely adapted to a particular function for enhancing the ability of the organism to survive.	a. design and conduct investigations and research on how an organism is uniquely adapted to a particular function for enhancing its ability to survive (1.2; 1.3; 1.4; 2.7; 4.6)	• Describe and compare internal and external structures of different plant and animal species that perform a common function (leaf structure of desert/tropical plants, tooth shapes of carnivores/herbivores, breathing organs of aquatic/terrestrial animals, etc.).

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The sorting and combination of genes in sexual reproduction results in a greater variety of possible gene combinations than in asexual reproduction that results in offspring genetically identical to the parent.	a. present a visual representation of variation in offspring due to sexual reproduction or how asexual reproduction results in genetic clones of the parent (1.3; 1.8, 3.5; 4.6)	• Design a laboratory inquiry with sexually reproducing organisms to study the transfer of genetic materials expressed as traits, from one generation to another. • Design laboratory inquires that allow observation of asexual reproduction in yeast, hydra, or plants and identify important characteristics of this type of reproduction. Discuss the difference between asexual and sexual reproduction.
2. Chromosomes are components of cells that occur in pairs and carry hereditary information from one cell to its daughter cells, and from a parent to its offspring.	a. use models to demonstrate how genetic material is transmitted and how gene traits are expressed in offspring (1.3;2.2)	• Demonstrate that chromosomes and genes come in pairs and are composed of many genes. Discuss how genetic material is transmitted. • Use Punnett squares and pedigree charts to demonstrate how single gene traits are expressed in offspring.
3. In sexual reproduction, each gamete contributes a set of chromosomes to the offspring, giving it the traits of both parents.	a. organize data, information, and ideas into a visual representation of the patterns and relationships involved in the chromosome contributions of gametes in sexual reproduction (1.6; 1.7; 1.10; 2.1; 3.2; 4.6)	• Describe sexual reproduction patterns in flowering plants and a variety of animals.
4. Each cell of a developing organism receives an exact copy of the genetic information contained in the fertilized egg.	a. organize data, information, and ideas to explain the stages through which a fertilized egg or seed changes into its adult form (1.2; 1.4; 1.8; 2.3)	• Observe, describe, and measure changes that occur in a bean plant, frog, or chicken as it develops from a seed or fertilized egg to an adult.

VII. Living Systems E. Adaptation/Evolution

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Natural selection is the process that ensures individuals with certain traits are more likely to survive and have offspring of the same species.	a. research the evolutionary adaptations of a number of present-day organisms and explain how these adaptations contributed to the survival of the organism (1.2)	• Describe the differences between short-term physiological adaptations (skin tanning, loss of a lizard's tail, calluses, etc.) and evolutionary adaptations occurring over generations (beak shape, protective coloration, flower color, etc.).
2. Changes in populations are often, but not always, driven by gradual or catastrophic changes in environmental conditions.	a. evaluate information, ideas, arguments, and products to determine patterns, relationships, perspectives, and credibility relating to changes in populations due to environmental conditions (1.5; 1.7; 1.8; 2.1; 2.4; 2.6)	• Observe and describe changes that occur during the development of animals. Explain how environmental factors could affect development.
3. A successful population can adapt to environmental changes through genetic variations.	a. present ideas, opinions, and arguments in an organized and convincing way stating the differences and similarities between successful populations and their environments (2.4)	• Conduct a natural selection simulation to demonstrate that a specific trait has selective advantage for an organism.
4. The study of fossil records and living organisms provides evidence of the appearance, diversification, and extinction of many life forms.	a. organize information and data to demonstrate the appearance, diversification and extinction of many lifeforms (1.5; 2.2)	• Create a timeline of the appearance and disappearance of different species in the fossil record. • Use technology and resources to describe the environment in Missouri during the time period in which a given fossil was living.

VII. Living Systems A. Structure/Function/Characteristics

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Cells are the fundamental structural and functional units of all living organisms and take highly varied forms in different plants, animals and microorganisms.	a. use appropriate technology and other resources to compare and contrast ways in which special cells carry out reproduction, photosynthesis, respiration, mitosis, meiosis, etc. (1.4; 1.6)	• Use microscopes to observe, sort and group cells according to their specific properties.
2. Cells have distinct and separate structures that perform and monitor processes essential for the survival of the cell and/or organism, such as chemical synthesis, energy conversion, material transport, and cell replication.	a. investigate, observe directly or indirectly, and communicate to others the basic life processes that take place at the cellular level (1.2; 1.4; 2.1; 2.3)	• Construct a simple experiment to compare the effect of concentration gradients on the movement of materials across cell membranes. • Use computer simulations or special lab materials and equipment to investigate chemical synthesis, energy conversion, cell replication and differentiation at the cellular level.
3. DNA indirectly controls what cells do and when they do it by conveying encoded information directing the cell's synthesis of protein molecules.	a. present perceptions and ideas explaining the process whereby DNA directs the synthesis of proteins from amino acids (2.4)	• Working in groups, create a computer animation illustrating the processes whereby DNA directs the synthesis of protein.
4. Organisms are classified into a hierarchy of groups and subgroups, based on their structural similarities and reflecting as much as possible their evolutionary relationships.	a. classify organisms into groups and subgroups based on structural similarities and then compare to published classifications of the same organisms based on evolutionary and molecular data (1.2; 1.6; 1.7; 1.8)	• Using a collection of toy organisms, classify them based on morphological features. Then compare and contrast this with actual evolutionary relationships of these organisms.

VII. Living Systems B. Life Processes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Cells carry out chemical transformations that allow conversion of energy from one form to another, the breakdown of molecules into smaller units, and the building of larger molecules from smaller ones.	a. use models to demonstrate various chemical transformations carried out by cells and apply this information to different contexts of everyday life (1.10; 2.7)	• Use models to demonstrate and discuss the mechanism of enzymatic action. Create skits that relate this process to an athlete's performance in a specific sport.
2. Photosynthesis and cellular respiration are complementary processes.	a. design and conduct investigations to determine what factors affect the processes of photosynthesis, anaerobic respiration, and aerobic respiration (1.7; 2.1; 2.2)	• Design tests involving elodea, a snail, and a pH indicator to develop reasonable explanations concerning the complementary relationship between photosynthesis and cellular respiration. • Conduct laboratory investigations to determine the requirements for and the products of photosynthesis. • Conduct investigations to determine how temperature affects the rate of cellular respiration of small invertebrates.
3. Optimum conditions are maintained in an organism as a result of special functions performed at the cellular level.	a. recognize and communicate logical relationships between general body conditions (such as fever or intoxication) and specific cellular processes (1.6; 2.4; 3.5)	• Carry out investigations of the effects of various drugs on the heart rate of daphnia.

VII. Living Systems C. Diversity

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Similarities in DNA and protein structure can be used to classify and determine degrees of kinship among organisms.	a. read and interpret representative examples of published primary articles discussing current research in the use of molecular similarities to determine degrees of kinship of organisms (1.2; 1.5; 1.7)	• Conduct a series of debates concerning the usefulness and accuracy of specific techniques used by scientists for determining degree of molecular similarity. • Use gel electrophoreses or data from gel electrophoreses to determine the genetic divergence and evolutionary relationship among species of plants and animals.
2. Variations of organisms within a species and diversity among species increase the likelihood that at least some organisms will survive in the face of large changes in the environment.	a. measure the amount of variation in a defined population of organisms, graph this variation, and relate this variation to the population's ability to survive environmental change (1.8; 3.5)	• Conduct a laboratory investigation or a simulation to demonstrate that variations within a species may enable organisms to survive large -cale environmental change.

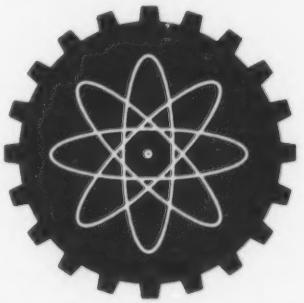
SCIENCE 9–12

VII. Living Systems D. Reproduction/Heredity

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Heredity/genetic information is contained in molecules of DNA that consist of various combinations of four different subunits that encode this information.	a. evaluate the accuracy of information provided in the news media regarding current topics related to genetics (1.7; 1.10; 4.1)	• In a mock criminal trial, use models of DNA, RNA, amino acids, etc., to learn about the structure of nucleic acids and the process by which DNA directs the synthesis of proteins.
2. The pattern of inheritance for many traits can be predicted by using the principles of Mendelian genetics.	a. using existing models that demonstrate patterns of inheritance (e.g., Punnett squares), make predictions as to probabilities and patterns of inheritance for resulting inherited traits in organisms (1.5; 1.6; 1.10; 2.2; 3.3; 4.1)	• Use Punnett squares and pedigree charts to determine probabilities and patterns of inheritance of seed shapes of pea plants.
3. Coding error in DNA synthesis (mutation) can occur randomly during replication and can also be caused by heat, radiation, and certain chemicals.	a. use models of DNA, RNA, amino acids, etc., to demonstrate how mutations affect the structure of proteins (1.6; 2.1)	• Conduct investigations of the rates of mutation in fruit flies resulting from exposure to various mutagens.
4. In asexual reproduction of unicellular organisms (and mitosis in multicellular organisms), DNA of parent cells replicates to form identical chromosomes and genes as the cell divides into two identical offspring cells.	a. create a visual representation of the molecular mechanisms that cause asexual reproduction to result in identical offspring and sexual reproduction to result in variation in offspring (1.3; 2.1)	• Use prepared slides and models of plant and animal cell mitosis to describe changes that occur during the cell cycle.
5. Embryological development in plants and animals involves a series of orderly changes in cell division and differentiation.	a. apply acquired information pertaining to embryological development to responsible decision making regarding health of developing human fetuses (1.3; 1.6; 1.7; 1.10; 3.5)	• Conduct investigations of the changes that take place in a plant seed as it develops into a mature plant and determine how development is affected by external and internal factors.

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Evidence for the nature and rates of evolution can be found in anatomical and molecular characteristics of living organisms and in the fossil record.	a. examining a real or simulated example of stratified layers of sediment containing fossils and analyze anatomical changes that occur from layer to layer. (1.2; 1.3; 1.6; 1.7; 3.5)	• Use anatomical and molecular characteristics of specimens, fossils, and models to illustrate the nature and rates of evolutionary change. • Examine the muscles, joints, and bones of an animal. Record similarities and differences to current models of its prehistoric ancestors.
2. The process of natural selection provides that some heritable variations that arise from mutation and recombination give individuals within a species some advantage over others for survival.	a. conduct laboratory experiments looking at artificial selection and apply the understanding acquired from these experiments to natural systems in which selection occurs because of environmental conditions. (1.2; 1.3; 1.6; 1.10)	• Participate in natural selection simulation activities in which students play the role of birds feeding on insects, picking colored toothpicks from piles of grass. The "survival" rate of "insects" of each color is recorded.
3. Evolution does not proceed at the same rate in all organisms; nor does it progress in any set direction.	a. research our present understanding of the course of evolution of specific types of organisms, identify random events that may have influenced this course, then predict possible alternative courses of evolution that could have resulted had these random events not taken place. (1.2; 1.6; 3.3; 3.5	• Examine fossil and modern horse anatomy to identify those traits that were perpetuated and those that were eliminated. Discuss possible reasons why one trait did not progress along a predictable path.

VIII. ECOLOGY
(SHOW-ME STANDARDS, SCIENCE 4)



A. Interactions
B. Changes

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K-12 Content Overview:

Knowledge of the living environment provides students with an understanding of their place in the natural world and of how humans can impact the environment to the benefit or detriment of themselves and other living organisms. Students generally know from everyday experience that in order to survive, organisms depend upon other organisms and the physical environment in which they live. But their awareness must be supported by knowledge of the types of interactions that occur among organisms, the kinds of physical conditions that organisms must cope with, and the complexity of the systems that are created through interdependence and interaction.

Living systems maintain a relatively stable internal environment through their regulatory mechanisms. Energy flows through an ecosystem from the Earth's primary source of energy, the sun, to organisms that can transform light energy into chemical energy. Other organisms then depend upon this chemical energy, in the form of food, to survive. While energy continually flows to Earth from the sun, matter on Earth is limited. Over periods of time, varying from days to eons, matter cycles between the living and nonliving environment.

The concept of evolution provides a framework for understanding the diversity and interdependence of life forms. All ecosystems change over time. Individual organisms that are best adapted to these new environments tend to survive and reproduce, leading to shifts in populations. The diversity of behaviors, structure, and biochemical characteristics within a population increases the likelihood that individuals will have characteristics that are beneficial in a changed environment.

VIII. Ecology A. Interactions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. All living organisms interact with each other and their environment.	a. give examples of how living things affect their environment and other living things (1.3; 1.6; 4.1)	• Investigate an outdoor plot to identify worms, bugs, birds, plants, etc. Give examples of how these things affect their environment and each other.
2. All organisms depend on one another and their environment to live and grow.	a. identify the common basic needs of organisms and the ways in which they depend on each other and their environment (1.1; 1.2; 1.3; 1.6; 1.10; 2.4; 3.5; 4.6)	• Study an aquarium and record how each organism contributes to the natural system of the aquarium. • Identify several animals that live in the local area. Investigate what food and environment they need to survive. • Investigate and discuss how different types of seeds are designed to be dispersed and the process of dispersal. • Design a fictitious animal or plant with the physical characteristics that will let it live and grow in a particular environment.
3. People depend on other organisms and Earth's resources for clothing, shelter, and food.	a. identify ways humans depend on other organisms for food, clothing, and shelter, etc. (1.2; 2.3; 4.1)	• Determine the sources of the different materials used to make clothes. • Chart the process by which food is grown, processed, and brought to our homes. • List common building materials and categorize them into "natural" or "human-made."

VIII. Ecology A. Interactions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
4.. Behavior patterns and survival of organisms result from their interactions with a specific environment.	a. predict how specific changes in the environment will affect people and other organisms found in this environment (1.1; 1.3; 2.4; 3.2; 3.4; 3.5; 4.1; 4.6)	• Plan and conduct simple investigations to explore how modifications in soil, water, and sunlight affectsthe growth and survival of a plant.
	b. identify behavior and physical adaptations that help organisms adapt to changing conditions (1.2; 1.5; 2.4)	• Explain how humans and animals are affected by temperature, rainfall, violent storms, earthquakes, floods, etc., and how they adapt.
	c. identify the physical attributes and behavior of living organisms that enable them to survive (1.2; 1.5; 2.4)	• Investigate and describe the habitat of an owl. Identify physical attributes and behaviors of the owls that enable them to survive in their environment.
5. Organisms interact with each other as producer/consumer, scavenger, predator/prey, parasite/host, decomposer, etc.	a. identify and discuss the nature of relationships between two or more living organisms (1.2; 2.3; 2.7; 3.5)	• List ways that hawks, mice, and plants interact in an ecosystem. Identify the interdependent relationships that exist (such as predator/prey).
6. Interactions between organisms and their environment contribute to continous cycling of matter and energy.	a. describe how organisms within a contained system maintain their relationships over time and what adjustments occur naturally within this system (1.1; 2.1; 3.1; 4.1)	• Conduct an extended investigation (terrarium, aquarium, local habitat) to explain how the inhabitants meet their energy needs. Generate reasonable questions about these interactions and design simple tests to investigate these questions.
	b. develop a food web to show the energy flow from any organism to another (1.8; 2.2; 3.5)	• Use pictures of plants, insects, birds, animals, and microorganisms to illustrate the flow of energy from producers to decomposers.

VIII. Ecology B. Changes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 2, all students should know that	*By the end of grade 2, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. All organisms, including humans, cause changes in their environments that can be either beneficial or harmful to the organisms in the ecosystem.	a. observe and record environment alchanges and the reactions of organisms to these changes over time (1.2; 1.5; 2.4; 3.1; 3.5; 4.1)	• Change the environment of a terrarium by changing the temperature and record how the invertebrates react. • Select a local area and investigate the influence of human activity on that area. • Investigate how modifications in a plant's environment (soil, moisture, sunlight) affect its growth and survival.
By the end of grade 4, all students should know that	*By the end of grade 4, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
2. Organisms that survive in an environment have developed adaptations that allow the organisms to compete for available resources and cope with the physical conditions of their environment.	a. identify positive adaptations of organisms to a given environment that increase chances for survival (1.3; 1.4; 2.3; 3.5; 4.1)	• Observe a variety of local plants and animals in an area. Identify the features of these organisms that make them suitable for that habitat.
3. Human activities can change the environment in ways that affect the health and survival of all living organisms.	a. explain how human activities can affect the environment in positive and negative ways (1.1; 1.2; 1.3; 1.4; 1.8; 2.1; 2.7; 3.5)	• Identify a classroom or school environmental issue (recycling, conserving electricity, cafeteria waste). Design and implement a plan to address the issue. • Investigate the impact of human activities or land development on various Missouri species (deer, opossum, turkey, buffalo clover, lady's slipper, etc.).
4. Changes in an environment, caused naturally or by humans, can be beneficial or harmful to the organisms living in that environment.	a. identify changes in an environment as beneficial or harmful (1.1; 1.2; 1.3; 1.4; 1.6; 1.8; 3.5; 4.1)	• Investigate how a pond changed over a 2-year period. Classify these changes as either a result of physical forces or from actions of humans. Identify the effects of the changes on the living organisms of that pond.

VIII. Ecology A. Interactions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. As energy flows through the ecosystem, all organisms must transform the portion of energy available to them into usable forms.	a. relate trophic levels and food webs to the flow of energy in an ecosystem (1.4; 1.6; 2.7; 3.5; 4.6)	• Investigate the relationship between the available energy in a local ecosystem and the types and numbers of species it will support. • Use the 10% law and design an ecological pyramid showing the energy contained in the biomass at each level.
	b. trace energy repossessions within specific food webs (1.4; 1.6; 2.7; 3.5; 4.6)	• Analyze a variety of food webs, identify the organisms at each trophic level, and account for the flow of energy from one trophic level to another.
2. Matter is recycled in an ecosystem, changing form and location.	a. relate energy flow and matter recycling to each step of a food web (1.4; 1.6; 1.8; 2.1; 3.5; 4.6)	• Describe how matter is recycled and some energy is lost in each step of a food web.
	b. explain the flow of matter and energy through an ecosytem and living systems (1.4; 1.6; 1.8; 2.1; 3.5; 4.6)	• Construct a flowchart to illustrate how matter, chemical nutrients, and minerals are cycled through the living and nonliving parts of an ecosystem.
3. Abstract concepts of global environment can be applied to complex interactions of the biotic and abiotic factors that affect populations and ecosystems.	a. speculate on the environmental changes that would have global impact and discuss the mechanisms by which the changes become global (1.1; 1.2; 1.3; 2.1; 3.5; 4.6)	• Investigate the "greenhouse effect" and relate it to possible changes in the biosphere. • Participate in policy formation simulations based on actual case studies involving the use of natural resources. Address the need to balance short-term economic policies with long-term resource planning.
4. All organisms, including humans, are part of and depend on one global food web that begins with organisms at the bottom of the energy pyramid.	a. apply the knowledge learned to describe examples of interacting organisms and classify them as beneficial, competitive, or detrimental to each other for survival (1.7)	• Construct simple diagrams of food chains to trace the flow of matter and to categorize the organisms of the food chain according to the function they serve. Use several food chains to design a food web that illustrates the interrelationships among the organisms in an ecosystem.

VIII. Ecology B. Changes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 8, all students should know that	*By the end of grade 8, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. The variation of characteristics in a population increases the likelihood that some members will survive the physical or biological changes of that system.	a. explain how the variation of organisms within a certain population increases the likelihood of survival of the species (1.2; 1.3; 1.10; 2.1; 3.8; 4.1)	• Investigate the response to disease and/or pests demonstrated by hybrid plant species developed for agriculture.
2. The diversity and balance of species in an ecosystem changes when environmental conditions change.	a. identify environmental changes that affect the diversity and balance of an ecosystem and suggest alternative approaches that are less intrusive (1.2; 1.4; 1.9; 2.1; 3.2; 3.3; 3.5; 4.1)	• Determine the amount of variation in population of mayfly larvae in streams. Compare this variation with the different water quality of the streams. • Investigate the change over time that plant communities may undergo growing along ditches, fences, edges of forests, under power lines, etc., may undergo. • Investigate case studies that indicate how humans impact the environmental conditions that affect the equilibrium of an ecosystem. • Analyze the human population data of a Missouri county or a city over a 100-year period. Discuss reasons for increases/decreases and the impact on the natural resources of the area.

VIII. Ecology A. Interactions

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. No two species occupy the same niche in an ecosystem so that different species can coexist and help maintain the stability of that system.	a. observe and identify competitive and cooperative interrelationships among species of a local ecosystem (1.1; 1.3; 1.4; 1.6; 2.4; 3.5; 4.1; 4.6)	• Evaluate the interrelationships of animals and plants of a local ecosystem. Identify ways they help maintain the stability of the ecosystem.
2. Human decisions concerning the use of resources can alter the stability and biodiversity of ecosystems.	a. research the methods of obtaining fossil fuels and their impact on ecosystems (1.4; 1.6; 1.8; 1.10; 3.2; 3.3)	• Explain the possible impact strip mining has on the ecosystem of the area in which it is used. • Research Missouri hunting or fishing regulations for a species and create a timeline comparing population numbers to changes in the regulations.
	b. explain the possible consequences of a reduction in biodiversity (3.1; 3.2; 3.3; 3.8)	• Research and discuss the consequences that may result from the reliance on one strain of wheat or one preferred animal stock.
3. Increased demand for natural resources require global cooperation and long-term planning to ensure the resource needs of successive generations will be met.	a. compare the use of natural resources in developing countries to the use in industrialized nations (1.2; 1.4; 1.7; 2.3; 2.7; 4.1; 4.6) b. discuss how technology has provided a more efficient use of resources and extended their availability (1.4; 1.7; 2.3; 2.7; 3.5; 4.1)	• Research and compare the use of natural resources in a Third World country to the use of natural resources of the United States. • Compare and contrast the process of getting food from the farm to the table before 1945 and after.

VIII. Ecology B. Changes

What All Students Should Know	What All Students Should Be Able To Do	Sample Learning Activities
By the end of grade 12, all students should know that	*By the end of grade 12, all students should be able to*	*These samples activities offer ideas and are not meant to limit teacher or student resourcefulness.*
1. Ecosystems are interconnected by biological, chemical, and physical processes so that changes in one ecosystem can have local or global consequences.	a. observe and identify biological, chemical, or physical processes of one ecosystem that affect other ecosystems (1.2; 1.4; 1.6; 2.3; 3.1; 3.5; 4.1)	• Investigate the effects of El Nino on plants and animals of the Midwest over the last 10 years.
2. Overpopulation in an ecosystem can lead to depletion of resources and elimination of a species.	a. identify the density-dependent limiting factors of a population and discuss consequences of overpopulation (1.6; 2.1; 2.3; 3.5; 4.1)	• Investigate the deer population in Missouri over the last 10 years. Discuss the pros and cons of harvesting the deer.
	b. discuss how changes in one population in an ecosystem affects the population of another species in that ecosystem (1.2; 1.4; 1.8; 2.1; 2.2; 2.3; 2.4; 2.7; 3.5; 4.1)	• Analyze and discuss how logging practices of the Pacific Northwest affected the northern Spotted Owls.
	c. identify the carrying capacity of an ecosystem and predict the limiting factors that will slow population growth (1.1; 1.4; 1.6; 1.8; 2.1; 3.5; 4.1)	• Explore the carrying capacity of the Earth for humans. Discuss the implications of a growing population on Earth's resources and possible lifestyle changes of humankind.

SUGGESTED PRACTICES FOR TEACHING AND LEARNING SCIENCE

The vision of science education in Missouri embraces the Teaching Standards of the National Science Education Standards (996) wherein effective teachers of science create an environment in which they and their students work together as active learners. While students are engaged in learning about the natural world and the scientific principles that can help them understand it, teachers are expanding their own knowledge about science, learning, and teaching. (For more in-depth dialogue, see the National Science Education Standards, available from the National Academy Press, 800-642-6242.)

ASSUMPTIONS

The following assumptions serve as a framework for identifying those strategies and techniques for best teaching science to all students. These assumptions should apply to those who teach in elementary, middle, and high schools as well as to faculty in higher education and instructors for workshops and seminars in less formal settings.

What students learn is greatly influenced by how they are taught. *

The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned in school. *

Student understanding is actively constructed through individual and social processes. *

Actions of teachers are deeply influenced by their understanding of their students and the relationships they have with them. *

Teachers are continuous learners, inquiring into the understanding of science, their students, and their teaching practice.

Science teachers do not act alone but require the full support of the entire educational system.

SCIENCE TEACHING STANDARDS*

The following are the Standards as reprinted by permission from the National Science Education Standards:

A. Science Teachers Plan an Inquiry-Based Science Program*

In doing this, teachers

- allow ample time for analysis, interpretation, and classroom discussion and encourage guessing, questioning, and exploration.
- use a mix of full-class activities, large-group presentation, cooperative learning, and individual projects or independent study.

*National Science Education Standards, 1996

- select science content and adapt and design curricula to meet the particular interest, knowledge, skills, and experiences of students.
- plan strategies that support the development of student understanding and nurture a community of science learners.
- work together as colleagues within and across disciplines and grade levels.

B. Science Teachers Guide and Facilitate Learning*

In doing this, teachers

- focus and support inquiries as they interact with their students.
- orchestrate discourse among students about scientific ideas.
- challenge students to take responsibility for their own learning and to work collaboratively.
- recognize and respond to student diversity and encourage all students to participate fully in science learning.
- encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas, and constructive skepticism that characterize science.

C. Science Teachers Engage in Ongoing Assessment of their Teaching and of Student Learning

In doing this, teachers

- systematically gather data on student understanding and ability.
- analyze assessment data to guide teaching.
- guide students in self-assessment.
- use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching.

D. Science Teachers Design and Manage the Learning Environment that Provides Students with the Time, Space and Resources Needed for Learning Science

In doing this, teachers

- structure the time available so that students are able to engage in extended investigations.
- create a setting for student work that is flexible and supportive of science inquiry.
- ensure a safe working environment.
- make the science tools, materials, print resources, and technological resources available to students.
- identify and use resources outside the school.
- engage students in designing the learning environment.

E. Science Teachers Develop Communities of Learners that Reflect the Intellectual Rigors of Scientific Inquiry and the Attitudes and Social Values Conducive to Science Learning

In doing this, teachers

- display and demand respect for the ideas, skills, and experiences of all students.
- give students a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
- nurture collaboration among students.

*National Science Education Standards, 1996

- structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse.
- model and emphasize the skills, attitudes, and values of scientific inquiry.

F. Science Teachers Actively Participate in the Ongoing Planning and Development of the School Science Program

In doing this, teachers

- plan and develop the school science program.
- have a voice in decisions concerning the allocation of time and other resources to the science program.
- plan and implement professional growth and development strategies for themselves and their colleagues.

VIGNETTES

The following vignettes, adapted with permission from the National Science Education Standards, 1996, are some examples of teaching for understanding. The teaching examples, presented as narration, focus on the richness and complexity of issues associated with teaching science. **The examples should be read with the following in mind:**

The examples are only examples. The examples are not meant to illustrate the full range of science teaching and assessment, but are examples of activities which may be used.

The examples are exemplary. The examples show teaching and assessment in the classroom as it will be when the practice of science education meets the criteria in this framework. Although the examples are visionary, the principles they demonstrate are attainable.

The examples are appropriate only if students have been involved in science education as described in the framework. The exercises are challenging but fair, if the students have had the opportunity to gain the understanding and skills needed prior to the exercises.

The examples are integrated across content strands. Although each example is associated with a primary content strand, nearly all of the examples integrate content from two or more strands.

All of the examples depend on students' ability to communicate scientific ideas. A long-term goal of science education is producing citizens who can speak and write intelligently about science-related issues. These examples were developed with the realization that students exhibit great diversity in their verbal and representational skills, as well as in their inclinations to speak in public.

*National Science Education Standards, 1996

K-4 Level

TEACHING FOR UNDERSTANDING ABOUT WEATHER* (Strands: Earth Systems, Inquiry, Relevance)

Mr. D.'s class was in charge of the school weather station as part of the schoolwide science program. In his planning for the weather station, Mr. D. had gone back over the objectives he and his colleagues had defined for the activity. Because of their age, the students would not be studying the actual causes of weather change such as air pressure, the worldwide air currents, and the impact of land and sea masses. Rather, over the course of the year, they would identify and observe the elements of weather; devise and use measurement and data collection strategies; build measurement instruments; analyze data to find patterns and/or relationships within the data; and communicate their work to the entire school.

Soon after the opening of school, Mr. D. introduced the weather station to the students. After a discussion on what the students' experiences and ideas of weather were, Mr. D. asked the class what kinds of information about weather they thought would be important to collect and how they might go about collecting it. The children quickly identified the need to record whether the day was sunny or cloudy, presence of precipitation, and the temperature. Mr. D. asked some questions and the list became more complicated: What kinds of clouds were there? How much precipitation accumulated? How did temperature change during the day? What were the wind speed and direction? One student said that he had heard on the weather report that there was a high pressure front moving in. What is a front, she asked, and is it important? At the end of the discussion, someone mentioned humidity, recalling the muggy heat wave of the summer.

When Mr. D. thought about the lesson and reviewed what he was going to do next, he realized that much of what the students had said was predictable. He wondered about the last two items— humidity and pressure. These concepts were well beyond students' ability to fully understand, yet they were familiar with the words. He decided to continue, as he had planned, on the more observable weather conditions and see whether the children's interests in humidity and air pressure were maintained.

The class spent time discussing and planning how they were going to measure the weather conditions, what tools would they need, and how they would collect and organize their data. Groups worked in the classroom and the library; each group chose one aspect of weather for its focus. Mr. D. spent some time with each group supporting their ideas, pushing them farther, and providing specific guidance when needed. He encouraged the groups to get together and compare notes. Twice during the week the whole class came together, and groups shared their work while students critiqued and offered ideas.

Several weeks later the weather station of the fourth grade was in operation. After much work, some trial and error, library research, and the helpful input of a parent who was a skilled mechanic, the children were recording data twice a day on wind direction and speed using a class-made anemometer and wind vane; temperature using a commercial thermometer (the students did make a thermometer following the directions in a book but decided that they would get better data with a commercial one); precipitation using a water gauge; and cloud formation. Design of the anemometer was extremely difficult. It was easy to build something that would turn in the wind but they had needed help in figuring how they would measure wind speed. The children were also measuring air pressure with a home-made barometer that a parent had

*National Science Education Standards, 1996

helped one group construct. Mr. D. supported this even though the children's ability to understand the concept was limited. The interest of the student and her parent and the classes' familiarity with the term seemed reason enough.

For 2 months, the students recorded their data on charts in the classroom. Then it was time to analyze the data, write the first report for the class weather book and make a report to the school. Again, the work began with a discussion. What were some of the ideas that the students had about the weather from all this measuring and recording? Were there patterns observed? Many students thought the temperature was getting lower; several noted that if it was windy one day, it rained the next day. As ideas were presented, other students agreed or challenged what was said. Mr. D. listened and wrote the ideas on a chart as the students spoke. When the discussion quieted, he turned the students' attention to the list and asked them to think about which of the ideas on the board they might actually be able to confirm by looking over the data. They listed several and agreed on the following list for a starting place: Was the temperature getting lower? What is the relationship between the direction of the wind and the weather the next day? What happened when the pressure went down or up? Was it colder when it was cloudy?

Mr. D. reminded the students of some ways they might represent the data to help them in the analysis; he assigned tasks, and the students returned to their groups. Several days later, the work was well under way. One group was working on a bar graph showing the total number of sunny, cloudy, and rainy days; another had made a temperature graph which showed daily fluctuations and that the weather definitely was getting colder; another made an interesting table that illustrated that, when air pressure dropped, the weather seemed usually to get worse. The next challenge was to prepare an interesting report for the school, highlighting all that had been learned.

The weather class continued to operate the weather station all year. Students became quite independent and efficient in collecting data. The data were analyzed about every 2 months. Some new questions were considered, while the basic ones continued. Midyear, Mr. D, satisfied that the students understood the use of charts and graphs, introduced a simple computer program that the students could use to log data.

Not only did students learn to ask questions and collect, organize and present data, they learned how to describe daily weather changes in terms of temperature, wind speed and direction, precipitation and humidity.

5-8 Level

TEACHING FOR UNDERSTANDING IN INQUIRY* (Strands: Force and Motion, Inquiry, Relevance)

The students in Ms. E.'s fifth grade class are studying motion, direction, and speed. One experiment is this study is designed to enable the students to understand how and why to change one variable at a time. Ms. E. has the students form groups of four: each student has an assigned role. One student—the materials manager—goes to the supply table to pick up a length of string, scissors, tape, and washers of various sizes and weights. Each group is directed to use these materials to 1) construct a pendulum, 2) hang the pendulum so that it swings freely from a pencil taped to the surface of the desk, and 3) count the number of swings of the pendulum in 15 seconds.

*National Science Education Standards, 1996

The note taker in each group records the result in a class chart. Ms. E. asks the students to examine the class data. Because the number of swings recorded by each group is different, a lively discussion begins about why this happened. The students decide to repeat the experiment to make sure that they have measured the time and counted the swings correctly. When the second set of data is entered on the class data table, the results make it clear that the differences are not because students did not count swings or measure time correctly. Again the class discusses why the results are different. Some of the suggestions include the length of the string, the weight of the washer, the diameter of the washer, and how high the student starting the pendulum held the washer to begin the swing.

As each suggestion is made, Ms. E. writes it on the board. The class is then asked to design investigations that could determine which suggestion is correct. Each group chooses to do an investigation to test one of the suggestions, but before the group work continues, Ms. E. collects the pendulums that were used to generate the first and second sets of data. As the groups resume work, one group keeps the string the same length but attaches washers of different diameters and tries to start the swing at exactly the same place. Another group uses one piece of string and one washer, but starts the swing at higher and higher places on an arc. A third group cuts pieces of string of different lengths, but uses one washer and starts the swing at the same place each time.

Discussion is animated as students set up their pendulums and the class quiets as they count the swings. Finally, each group shares with the rest of the class what they did and the data they collected. The class concludes that the difference in the number of swings that the pendulum makes is due to the different lengths of string.

The next day, students notice that Ms. E. has constructed a board for the pendulums at the front of the room. Across the top are pegs from which to hang pendulums and across the bottom are consecutive numbers. The note taker from each group is directed to hang the group's original pendulum on the peg corresponding to its number of swings in a fixed time. When all of the pendulums are hung on the peg board, the class is asked to interpret the results. After considerable discussion, the students conclude that the number of swings in a fixed time increases in a regular manner as the length of the string gets shorter.

Ms. E. notes that pendulums were constructed with five and seven swings per 15 seconds on the peg board, but no pendulum with six; she asks each group to construct a pendulum with six swings per 15 seconds. After much measuring and counting and measuring again, and serious discussion on what counts as a "swing," every group declares success. Ms. E. then asks how they can keep the information on the relationship between the length of the string and the number of swings in a form that is more convenient than the peg board and directs the students to make a drawing in their science journals to keep those data. Most students draw the peg board with the pendulums of different lengths, but some students draw charts and a few make graphs. Ms. E. challenges students to find examples of pendulums at home and in their neighborhoods.

The next science class is spent discussing graphing as students move from their pictures of the string lengths, to lines, to points on a graph, and to a complete graph. Finally, each student is asked to use his or her graph to make a pendulum that will swing an exact number of times.

Students have described, explained, and predicted a natural phenomenon and learned about position and motion and about gathering, analyzing, and presenting data.

*National Science Education Standards, 1996

9-12 Level

TEACHING FOR UNDERSTANDING ABOUT SCIENTIFIC RELEVANCE* (Strands: Ecology, Living Systems, Relevance, Inquiry)

Mr. H. was beginning the second round of planning for his high school biology class. He set aside 3 weeks for a unit on green plants. Now it was time to decide what would happen during those three weeks. Students came to his class with some knowledge and understanding about green plants, but they still had many questions. As a way to get students to focus some of their questions, and to highlight the interdependence of science and civilization, he was going to begin the unit with a lecture on photosynthesis. Lecturing was something he seldom did. However, the purpose here was not to lay out the complex details of the photosynthetic process, but to illustrate how the scientific community's knowledge of photosynthesis had changed over time.

He would begin the lecture by putting a transparency on the overhead projector that detailed diagram of photosynthesis that had been sent to him free from one of the pharmaceutical companies. One of the high school textbooks that he kept as a reference said that scientists now had described 80 separate but interdependent reactions that make up photosynthesis. He would ask the students how long the scientific community had known about these many complex reactions; why this knowledge was important; how they had come to know so much; were there still more details to be described. This was a pretty good list of questions. In yellow highlighting ink, he wrote the word "wait" in his notes, to remind himself that he needed to give the students time to think before they gave an answer to his questions.

Next, he would ask students to tell him what they already knew about photosynthesis. He expected most would recall that carbon dioxide, water, sugar, oxygen, and sunlight are important and many would recall growing plants in dark cupboards and under boxes in intermediate school. The next two questions would have to be worded carefully: Why is photosynthesis so important? Or, put another way, what is the fundamental question that photosynthesis answers and how long have scientists known about photosynthesis?

With this introduction, he would lecture about the 17th century experiment of von Helmont and his tree, and his conclusion that the weight of plants came from water. Mr. H. would pause, "Was van Helmont wrong?," he would ask the students. He expected them to have difficulty conceiving that van Helmont had conducted an experiment, which they know was essential to science, but that he had not obtained the answer they knew was correct. Mr. H. would help them analyze the experiment and the conclusions that could legitimately be drawn from it. He would then introduce more of the context of van Helmont's investigation: the prevailing belief about plants as a combination of fire and earth and how van Helmont's study was designed to refute this belief. He would comment that many researchers chose to repeat the tree study, and then he would allow students to discuss how (or whether) van Helmont's study had contributed to the science of photosynthesis.

He would then continue his historical lecture using similar details from several other episodes. He would describe how chemists had learned to collect gasses from chemical reactions, how Priestley used these new techniques, and how he then observed the effect that gases from plants produced on burning candles. He would note that Priestley did not know about oxygen, but

*National Science Education Standards, 1996

viewed it as a purer form of air. He would mention how Ingenhousz expanded Priestley's finding by showing that the air was changed only when the plants were kept in sunlight, and how de Saussure confirmed that carbon dioxide was a gas needed for the same effect. He would detail how James Hutton had been involved in industrial debates about the quality of coal and was interested in why coal burned. Hutton had interpreted plant imprints in coal as a clue that something from the sun was being stored in plants and then fossilized as coal. The "something" would later be released again as light as the coal burned. But Hutton had no concept of chemical or light energy—concepts introduced only decades later by Julius Mayer. Mr. H. would stop his history here. Students would review how various factors had shaped the development of early knowledge about photosynthesis. He would record and organize their views on the chalkboard. From this they would develop a set of questions for continuing the history on their own.

Mr. H. had collected a number of textbooks from different periods in the century. He would introduce them as a resource for sketching the changing status of knowledge about photosynthesis. He would have the students work in groups of five. Each group would prepare a brief presentation on ideas of photosynthesis during a particular historical period. After 2 days to gather information, each group would share the result of its research and together the students would identify or infer what discoveries had been made in each period. Then, using the questions they had formulated earlier, the students would return to their groups to determine how each discovery had occurred. They would identify factors such as new technologies that were relevant to conducting investigations, the sources of funding for various research projects, the personal interests of researchers, occasions of uick or chance, and the theories that had guided research. Finally, each group would share two patterns that they had uncovered and how they had reached their conclusion.

Through this activity, students would come to realize that scientific understanding does not emerge all at once or fully formed. Further, the students recognized that each new concept reflected the personal backgrounds, time, and place of its discoverers. At the very end of the period, Mr. H. would ask the students to speculate on what scientists might ask about photosynthesis today or in the future and what factors might shape their research.

*National Science Education Standards, 1996

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APPENDIX A

EXAMPLES OF QUALITY STUDENT WORK

The right-hand column of these Frameworks lists many suggestions for classroom activities. Simply listing activities, however, may not communicate in a concrete way what constitutes quality student work in science. This appendix addresses that need by providing a few examples of quality student work to illustrate what is possible.

There are three limitations to this appendix. First, only a few examples of student work are provided because reviewers advised the authors not to make the framework too long. Second, items in this appendix will not cover *all* of the many important topics Missouri science teachers teach. Finally, some of the examples have imperfections, maybe a spelling error or two, a computational error, or a minor error of fact. We included the examples with their mistakes not because we want to promote sloppy spelling, computational errors, or factual misinformation, but because the examples are real products of students who possess other strong redeeming qualities.

Despite those limitations, the examples shown should enable readers to visualize what Missouri students should be able to do with regard to the Show-Me Standards in science. The following examples were developed by The New Standards Project of which Missouri is a partner.

ELEMENTARY SCIENCE ACTIVITY

"Flinkers" *

Task

Students were instructed to complete a laboratory activity in which they adjusted the mass and/or the volume of an object so that the object would not float on top of water or sink... it would "flink." Students are to first explore a range of available floating and sinking objects.

Show-Me Knowledge Standards Addressed

SC 1 properties and principles of matter and energy
SC 2 properties and principles of force and motion

Show-Me Performance Standards Addressed

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.3 design and conduct field and laboratory investigations to study nature and society
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.8 organize data, information and ideas into useful forms for analysis or presentation
2.3 exchange information, questions and ideas while recognizing the perspectives of others
2.4 present perceptions and ideas regarding works of the sciences
3.1 identify problems and define their scope and elements
3.3 develop and apply strategies based on one's own experience in preventing or solving problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.6 examine problems and proposed solutions from multiple perspectives
3.7 evaluate the extent to which a strategy addresses the problem
4.1 explain reasoning and identify information used to support decisions
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals
4.6 identify tasks that require a coordinated effort and work with others to complete those tasks

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Student Work

SCIENCE ENTRY SLIP

Your name_____ Date work was completed Feb. 6
Date work placed in portfolio Feb. 6

What was the assignment? (Attach a copy if possible)

To get the mass and volume of an object to equal 1 so it wouldn't float or sink, it would flink.

Is this part of a long-term investigation or a shorter task?

A short task.

Who selected this piece of work?

_____

What tools or resources did you use? How much feedback or help did you get from your teacher or other adults?

We used things from home that would float and others that sank and put them together just right. My partners mom helped us try out different combinations.

Did you work alone or with a group?

I worked with a partner.

What do you want the reader to notice about this work? Why did you select this piece of work?

That it took determination and patience to get an object to flink, but it was also fun.

What were the important scientific ideas in this task?

To learn about floating, sinking, and density.

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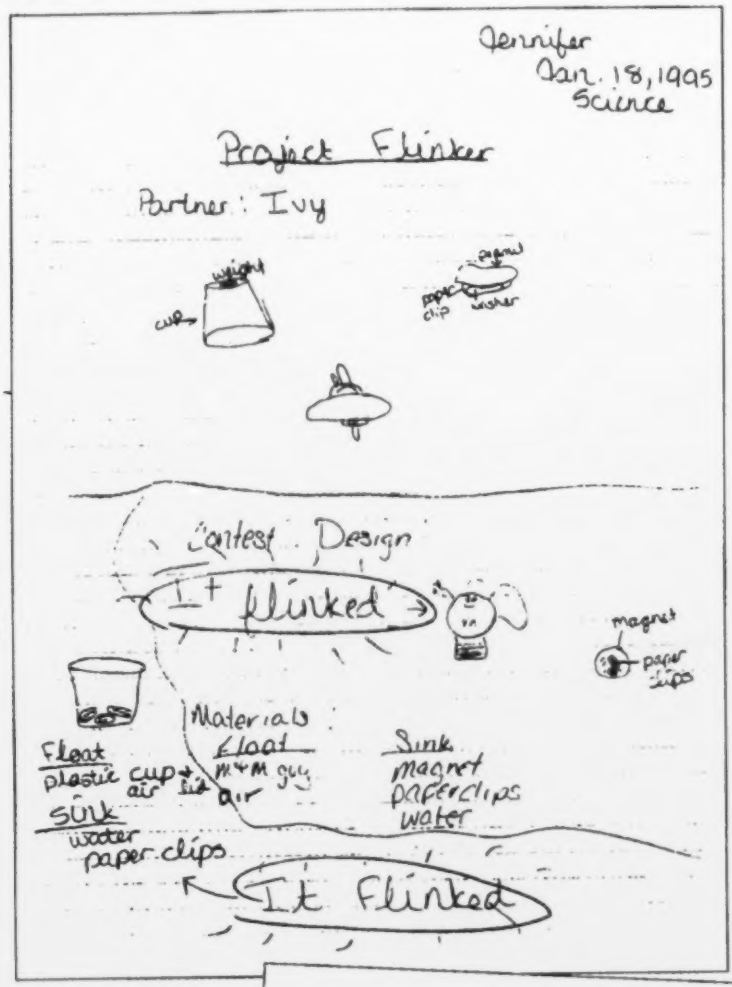

The flinker lab was an enjoyable way to learn about why things float and sink. To make something flink, the mass and the volume had to equal one. And to do this, you had to use a prosess of trial and error to get them to equal 1. One reason we had trouble is that some things absorbe water and that gives it more mass. But we finally made a creative design that flinked with some floating things and some sinking things.

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Commentary

In engaging this task, the student performed a simple experiment, accomplished by trial and error, in which an object became neutrally buoyant. The part of the work which explains why an object became neutrally buoyant is evidence for an elementary understanding of observable properties of objects and materials: "to make something flink, the mass and the volume had to equal one." The additional explanation, that "some things absorbe(sic) water and that gives it more mass," shows understanding beyond the elementary level and leads towards a middle school understanding of density.

This work sample illustrates elementary school level conceptual understanding of the observable and measurable property of density. Sufficient evidence of understanding of density is represented by the statement: "to make something flink, the ratio of the mass and the volume had to equal one"; or "to make something flink, the mass divided by the volume had to equal one." Further, and although this is perhaps taken for granted, an adequate middle school response would make explicit the density of water, which equals one.

The explanation, wherein things that absorb water increase in mass, is clear evidence for an awareness of the connection between mass and floating or sinking. The work shows that the final product was constructed by combining "some floating things and some sinking things." This shows that the objects had been sorted into different classifications based upon an observable characteristic (floating or sinking).

This work sample is an unrevised laboratory report. There are three spelling errors ("prossess," "absorbe," and "detirmination") and a missing apostrophe ("my partners mom").

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ELEMENTARY SCIENCE ACTIVITY

"Drop of Water" *

Task

After a two-week unit on weather which included the water cycle, students were asked to write a story about a drop of water that goes through the water cycle.

Show-Me Knowledge Standards Addressed

SC 1 properties and principles of matter and energy
SC 5 processes (such as plate movement, water cycle, air flow) and interactions of earth's biosphere

Show-Me Performance Standards Addressed

1.5 comprehend and evaluate written, visual, and oral presentations and works
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.7 evaluate the accuracy of information and the reliability of its sources
1.8 organize data, information and ideas in useful forms for analysis or presentation
2.1 plan and make written, oral, and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.4 present perceptions and ideas regarding works in the sciences
3.3 develop and apply strategies based on one's own experiences in preventing or solving problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.7 evaluate the extent to which a strategy addresses the problem
4.1 explain reasoning and identify information used to support decisions
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals

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Student Work

My Big Trip
by Jason

Good morning, I am Mr. H. Tuoh. I just woke up and the sun is coming up. I have been swimming with my friends in a nice lake in Nebraska. Since I am on top of this pile of sleeping friends the sun is going to take me for a ride today.

Wow, that was fast. I am climbing really fast. I feel bigger. That's because I am a gas . It happens every time I get hot. When I get cold I get smaller. They call me a solid. Being solid gives me a headache. This is better than World's of fun! There is a big cloud ahead and we are slowing down. I am getting smaller now because my pants fit better. But, it's getting really crowded!!! I can hardly move. Who let in the ugly dust family? I think I will hang on to this dust guy so I can rest up. Hey, everybody is coppying my idea and we are getting heavy. Oh Noooooooooooooo we are falling!!! But that's OK because I was getting really cold.

What a trip. I am almost back to the lake. Wait, where is the lake. This looks like a big river . I don't think I am going to hit the river. Oh nooooooooo .I better put on my crash helmet and prepare for a land landing. OUCH! That hurt. But, at least I am down. hey, we are moving again. These dirt and rock hurt. Do they have to come along on MY trip?

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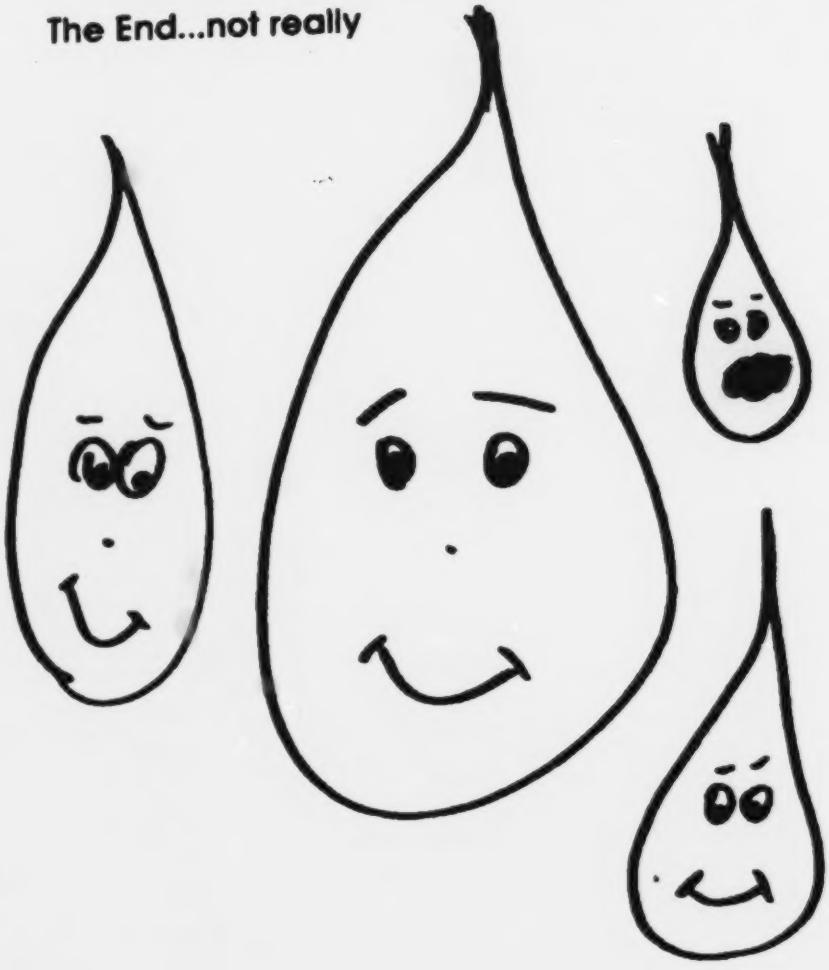
Wow, I am in the Mississipi river! There are lots of us and mud and rocks and stuff. I feel kind of dirty. I wish I could go up to sit in the clouds a while. I will just sit back and float a while. Oh, here comes the sun. Here I go again. I wonder where I will end up this time.

The End...not really



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Commentary

This work shows a deep level of conceptual understanding in physical sciences for an elementary student. By using the first person voice, the work sample represents abstract concepts in the water cycle, e.g., the spacing of molecules, in terms an elementary student would understand. Conceptual understanding of the water cycle is evident in the details of the journey from a lake in Nebraska to the Mississippi river and in the statement "The end, not really."

This work provides evidence for understanding of phases of matter. Deep understanding is shown in the representation of relationships among phase, temperature, and volume. For example, "I feel bigger. That's because I am a gas. It happens every time I get hot. When I get cold, I get smaller. They call me a solid."

This work also provides evidence for understanding the Earth's systems and the processes of those systems. Several key steps are included:

"The sun is going to take me for a ride today" (Evaporation caused by the sun)
"I am climbing really fast" (Upward movement of water vapor)
"I am getting smaller...it's getting really crowded" (Condensation)
"I think I will hang on to this dust guy" (Formation of heavier drops)

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MIDDLE SCHOOL SCIENCE ACTIVITY

"Passive Solar Homes" *

Task

Students were asked to design and build a model which would illustrate a form of renewable energy and to make a presentation.

Show-Me Knowledge Standards Addressed

SC 1 properties and principles of matter and energy
SC 5 processes and interactions of earth's biosphere, atmosphere, lithosphere, and hydrosphere
SC 7 processes of scientific inquiry (such as formulating and testing hypotheses)
SC 8 impact of science, technology and human activity on resources and the environment

Show-Me Performance Standards Addressed

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.4 use technological tools and other resources to locate, select, and organize information
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.7 evaluate the accuracy of information and the reliability of its sources
1.8 organize data, information and ideas in useful forms for analysis or presentation
2.1 plan and make written, oral, and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.3 exchange information, questions, and ideas while recognizing the perspectives of others
2.4 present perceptions and ideas regarding works in the sciences
3.1 identify problems and define their scope and elements
3.2 develop and apply strategies based on ways others have prevented or solved problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.6 examine problems and proposed solutions from multiple perspectives
3.8 assess costs, benefits, and other consequences of proposed solutions
4.1 explain reasoning and identify information used to support decisions
4.4 recognize and practice honesty and integrity in academic work
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals
4.6 identify tasks that require a coordinated effort and work with others to complete those tasks

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Student Work

Passive Solar Homes

Solar energy can be used in many ways. It can be used to heat water, cook food, and even heat and provide energy for homes. It is a very reliable source.

Passive solar homes run on passive solar energy. The home is equipped with special devices to run on solar energy. It is equipped with a black asphalt roof to collect, store, and distribute the heat. It also has full length windows on the south side for the sunlight to pass through and collect in the insulation inside the walls. There are also windows on a slanted roof for extra sunlight. The house has flagstone or adobe floors and walls for heat storage. To prevent overheating the house is equipped with ventilation, overhangs, shades, and landscaping.

The energy passes through the windows and heats the air. Then the walls and floors absorb and store excess heat. The stored heat is later released when the temperature falls. When the energy passes through the windows and is collected in the walls, then later released the energy conversion from this is light to heat. The sunlight is stored as heat and later released.

Solar energy is a renewable source. It comes only from the sun. The sun can't run out of energy until it stops burning. The sun is always burning, therefore, solar energy is renewable. Solar energy will always be renewable until the sun stops burning.

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The cost efficiency for having a solar home is very inexpensive. The only thing needed for a solar home is large windows, insulation in the walls and floors, and adobe or flagstone. Solar energy does not need extra energy to run it, therefore, there are no extra costs. Solar energy is not wasteful and is a low-cost system.

A passive solar home provides day lighting and improves comfort with radiant heat. Solar energy is a renewable heating system that is quiet and reliable, has low maintenance, no moving parts, and lasts longer than other heating systems. The solar home also has a minimum impact on the environment. It uses no gas, coal, petroleum, or any other polluting energy sources. It uses only the sun which does not pollute the environment or harm it in any way.

Solar energy has very little impact on society. Positive impacts on society are that solar homes do not pollute, and are less costly for the government and homeowners. Negative impacts are that parts of society do not agree with the solar energy idea. Also, redesigning of houses and subdivisions would have to take place to fit the needs of solar energy.

Solar energy is a very easy and productive resource. It is environmentally safe and does not cost much at all. Solar energy is the ideal renewable energy source.

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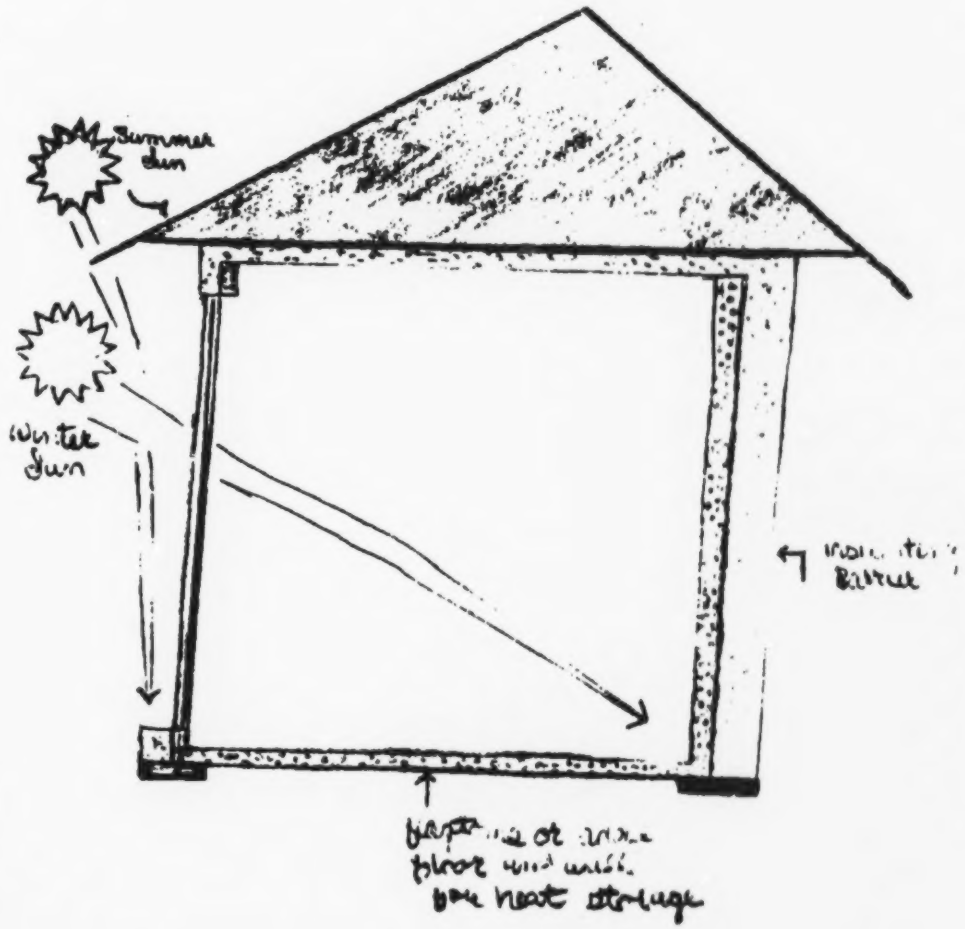
Passive Solar Energy

The sunlight passes through the window, then is directed and stored in the insulating barrier. Later when the temperature falls the heat is released.



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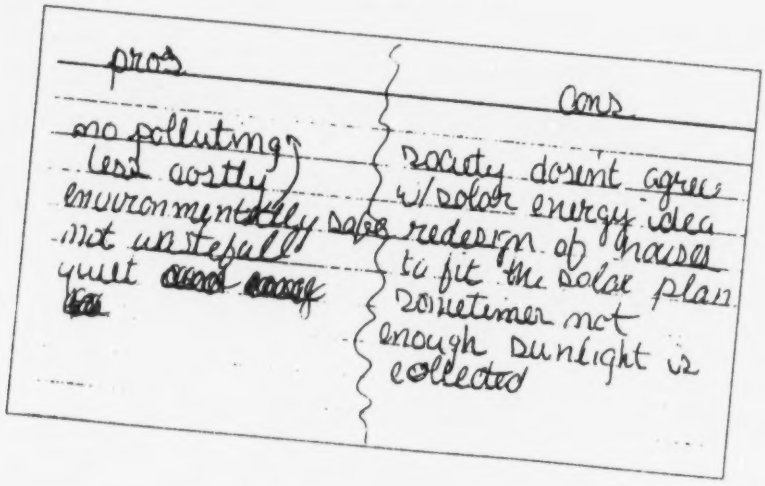
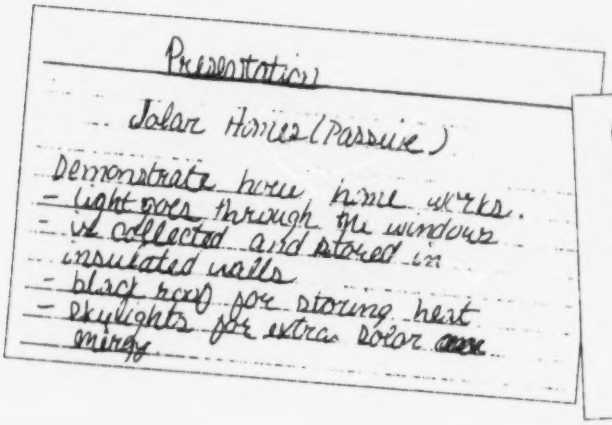


pros

- no polluting
- less costly
- environmentally safe
- not unsteady
- quiet

cons

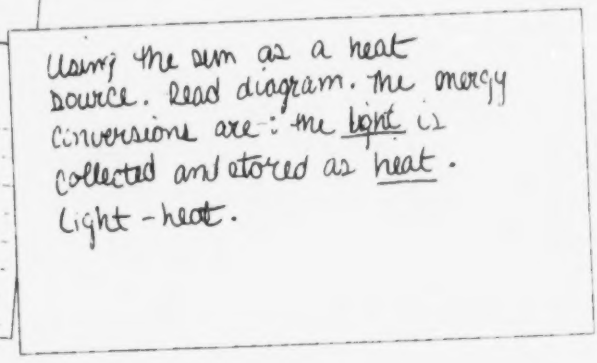
- society doesn't agree w/ solar energy idea
- redesign of houses to fit the solar plan
- 20 minutes not enough sunlight is collected



Presentation

Solar Homes (Passive)

Demonstrate how home works.
- light goes through the windows
- it collected and stored in insulated walls
- black roof for storing heat
- skylights for extra solar energy



Using the sun as a heat source. Read diagram. The energy conversions are: the light is collected and stored as heat.
Light - heat.

Commentary

This student chose the topic of passive solar homes. Included here are the written report, a design drawing, and notes for the presentation. The model was built but is not included here.

The discussion of heat and light energy, renewable resources, and the benefits of solar energy in this work provides evidence for the quality of work expected for understanding the concept of natural resource management. An explanation of solar heating and how it captures energy provides the framework from which a knowledgeable design is made and the model constructed, i.e., "The energy passes through the windows and heats the air". The student's explanation of the purpose for each of the components of a passive solar home is evidence for understanding the concept of form and function, particularly the second paragraph of the written report, from "It is equipped with a black asphalt roof to collect, store, and distribute heat..." to "To prevent overheating, the house is equipped with ventilation, overhangs, shades, and landscaping."

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The analysis of tradeoffs, part of an understanding of technology, is evident in the presentation notes under the titles "pros" and "cons." Attention to tradeoffs is also present in the written report. Both the positive impacts (such as "solar homes do not pollute, and are less costly for government and homeowners") and the negative impacts (such as "redesigning of houses and subdivisions would have to take place to fit the needs of solar energy") are noted, and a conclusion is drawn: that solar energy is a cost efficient and productive resource. Recognition of the transformation of light energy to heat energy is apparent in the statement, "The sunlight is stored as heat and later released." The underlined forms of energy are emphasized in the student's work which provides evidence for understanding transfer and transformation of energy.

This work could be strengthened by addressing the drawbacks to solar energy: for example, how to harness the energy so that it is available at night or at times when the sky is cloudy, as well as the need for an appropriate climate. This work does not address the issue of moving the heat from the roof to the inside of the house or throughout the home with ventilation fans.

This work is sufficient quality for the middle school level. It would be powerful for this investigation to be revised by the same student two years later, after more experience with science concepts.

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MIDDLE SCHOOL SCIENCE ACTIVITY

"Cruise Boats" *

Task

Students were asked to explain how cruise "boats" move and to explain the concepts at a level that could be understood by five- to ten-year-old children.

Show-Me Knowledge Standards Addressed

SC 2 properties and principles of force and motion
SC 7 processes of scientific inquiry (such as formulating and testing hypotheses)

Show-Me Performance Standards Addressed

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.3 design and conduct field and laboratory investigations to study nature and society
1.4 use technological tools and other resources to locate, select, and organize information
1.5 comprehend and evaluate written, visual, and oral presentations and works
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.8 organize data, information and ideas in useful forms for analysis or presentation
2.1 plan and make written, oral, and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.3 exchange information, questions, and ideas while recognizing the perspectives of others
2.4 present perceptions and ideas regarding works in the sciences
3.1 identify problems and define their scope and elements
3.2 develop and apply strategies based on ways others have prevented or solved problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.6 examine problems and proposed solutions from multiple perspectives
4.1 explain reasoning and identify information used to support decisions
4.4 recognize and practice honesty and integrity in academic work
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals

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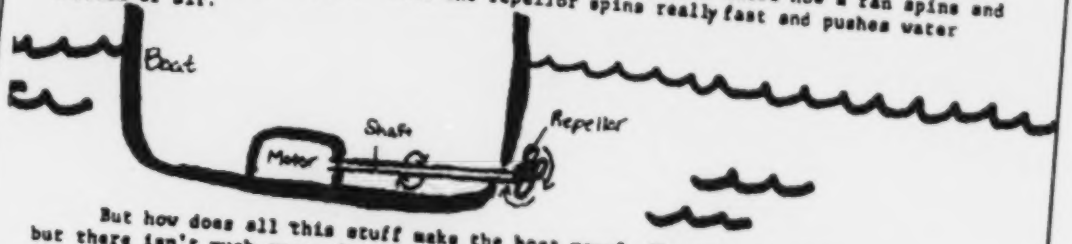
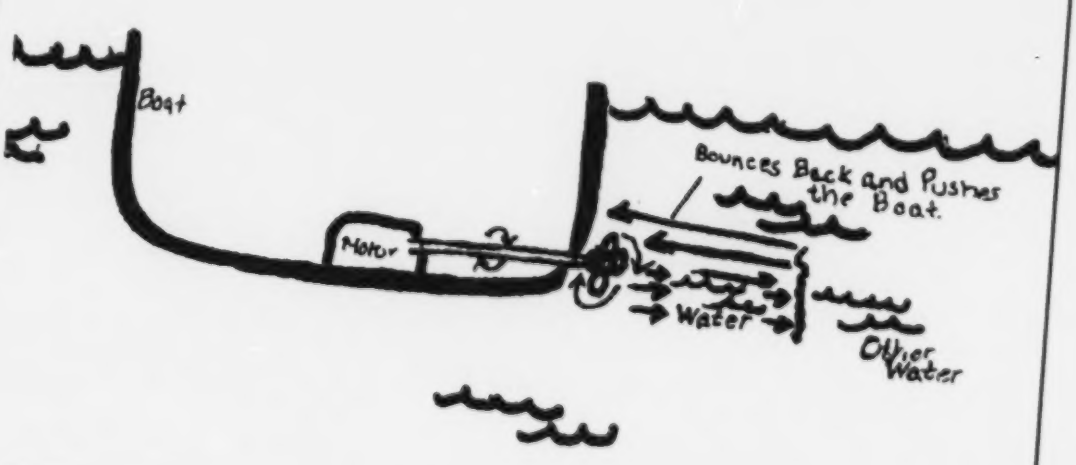
Student Work

Cruise Boats and How They Move

How does a cruise boat move? Well for one thing, something has to be pushing it. Like for example, take your toy truck. To make your truck move you have to push it. Well a cruise boat has to be pushed too. But what pushes the cruise boat? A motor does. And since a cruise boat is really big this has to be a special motor. The motor is like a big battery. The motor makes enough energy to spin a shaft. A shaft is a special medal pole or stick. The shaft is connected to a repellor. What is a repellor? A repellor looks like a fan. Everyone knows how a fan spins and pushes air to cool you down. Well the repellor spins really fast and pushes water instead of air.



But how does all this stuff make the boat move? The repellor pushes water, but there isn't much space for the water to go because other water is around it. So the water pushes the boat forward so it has more room.



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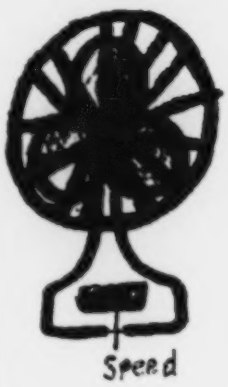
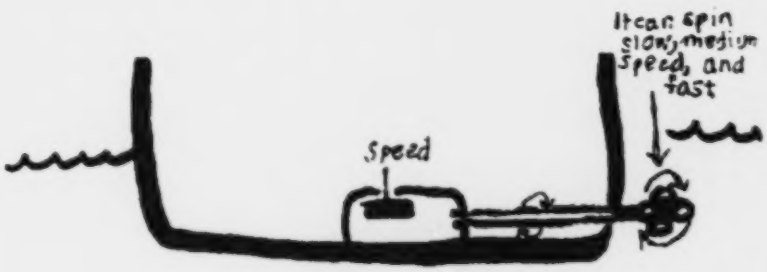
But what if you want the cruise boat to go fast? Well like a fan that you use to cool yourself down you can change the speeds so that it goes slow, medium speed, or fast. Well just like the fan, the cruise boat can change its speeds so that it can go slow, medium speed, or fast.

To make it go fast you tell the motor to spin the repellor a lot faster. The faster the repellor is spinning the more water is being pushed. And that means it's going to push the boat ahead farther.





And that's how a cruise boat works!!

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Commentary

It is not clear if the student did any investigations in water to construct this explanation. However, the student did engage the task and connected previous learning and a variety of concepts to explain something with which he/she may not have had direct experience.

The relationship between force and motion is easier to illustrate in an environment familiar to the student. To explain the forces in a liquid medium forces the student to apply the concept in an unfamiliar setting. This student successfully explained that when you have a force in one direction you must have a resultant force in the opposite direction (pushes the boat forward). However, the student mistakenly attributes the push to water bouncing back. The actual force is not a bounce but simply a force resulting from the movement of water in reverse (thus moving the boat forward). The germ of a correct mechanism for the push by the water on the propeller is there in the "resistance" of the water being pushed away. The student later correctly explains that the faster the movement of water (linked to the fan analogy) the faster the forward movement of the boat.

It is important to note that the task was about the forces making the boat move and not about the energy necessary to turn the propeller. The early explanation that a motor is like "a big battery" is incorrect. Boats do use chemical energy (fuel) to release heat, and it is this heat energy and not electrical energy that powers the boat. However, since the task did not ask for an analysis of energy transformations, this misconception did not take away from the student's work here.

The student's use of the fan to explain how ships might move faster is evidence that the student understands the link between the shape of the fan and the behavior of a similar design in a different setting (water). The idea of cause and effect is illustrated when the student explains that as the fans move faster more water is pushed causing greater forward motion.

The task asked for an explanation to a specific audience (five-to ten-year-olds). Concepts are represented in multiple ways; the use of drawings is an effective way to illustrate the forces operating in this system. There is an appropriate level of detail necessary for a complete explanation to a younger student.

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HIGH SCHOOL SCIENCE ACTIVITY

"Are Oysters Safe to Eat?" *

Task

The National Science Research Center encourages the establishment of student research centers in schools in the United States and around the world. The Center facilitates the exchange of information by publishing a journal of student investigations and by use of the Internet (nsrcmms@aol.com). It provides a standard format that students use to report their results. The format requires that students state a purpose and hypothesis; report their methods, data analysis, and conclusions; and suggest applications for their results. The following student sample is from a student who decided to study whether oysters in her area were safe to eat.

Show-Me Knowledge Standards Addressed

SC 1 properties and principles of matter and energy
SC 3 characteristics and interactions of living organisms
SC 7 processes of scientific inquiry
SC 8 impact of science, technology and human activity on resources and the environment

Show-Me Performance Standards Addressed

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.4 use technological tools and other resources to locate, select, and organize information
1.5 comprehend and evaluate written, visual, and oral presentations and works
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.7 evaluate the accuracy of information and the reliability of its sources
1.8 organize data, information and ideas in useful forms for analysis or presentation
2.1 plan and make written, oral, and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.3 exchange information, questions, and ideas while recognizing the perspectives of others
2.4 present perceptions and ideas regarding works in the sciences
2.7 use technological tools to exchange information and ideas
3.1 identify problems and define their scope and elements
3.2 develop and apply strategies based on ways others have prevented or solved problems
3.4 evaluate the processes used in recognizing and solving problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.6 examine problems and proposed solutions from multiple perspectives
4.1 explain reasoning and identify information used to support decisions
4.4 recognize and practice honesty and integrity in academic work
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals
4.6 identify tasks that require a coordinated effort and work with others to complete those tasks

Student Work

TITLE: Louisiana Oysters: Are They Safe to Eat?

I. STATEMENT OF PURPOSE AND HYPOTHESIS:

The purpose of my research is to try and find out if raw Louisiana oysters, that many people love, are safe to eat. Studies have been done on the oysters to find out if they are harmful to humans, and many of these studies contradict one another. My hypothesis states that forms of salmonella and e. coli bacteria will be present in the oysters I test.

II. METHODOLOGY:

I began my research by stating my hypothesis and doing a review of the literature about the diseases caused by the eating of raw oysters. With this information, I developed a methodology and list of materials that would help me measure the amount of bacteria present in oysters, the amount of the bacteria that can be safely consumed, and the length of time needed to cook the oysters so that they are safe to eat.

For materials, I used twenty raw Louisiana oysters, boiling water for sterilization, a sterilized blender, an incubator, sterile swabs, four petri dishes, a tryptic soy agar with 5% sheep blood.

I began by sterilizing all equipment with boiling water for ten minutes. I then took five of the raw oysters and placed them in the blender until they were ground up. Then, using one of the sterile swabs, I smudged a small amount of the liquid from the oysters onto a petri dish. I then steamed five oysters for one minute, another five for three minutes, and another five for five minutes. I then ground up each of these groups of oysters separately and smudged a small amount of the liquid from each onto three different petri dishes. Next, I incubated all four of the petri dishes for about forty-eight hours. Then I counted the colonies and identified the types of bacteria that were present in each petri dish. I also determined what amount of each type of bacteria could be safely consumed.

III. ANALYSIS OF DATA:

The bacteria count in the raw oysters was much greater than in the steamed oysters because the steaming did kill many of the bacteria. However, the oysters that were steamed for three minutes contained less bacteria than the ones that were steamed for five minutes. This may have been due to the fact that I had a random selection of unweighed oysters in each group of oysters. Some of the oysters were larger than others and the heated steam may not have penetrated as deeply into them. Therefore the larger oysters may not have been as fully cooked and the bacteria in them not fully killed, causing this result.

In the five types of colonies found, one was a vibrio which is the worst bacteria and the second worst thing you could eat in an oyster. Vibrio cause gastroenteritis that may lead to bacturimia if the bacteria moves into the blood. The other four colony were types of pseudomonas that aren't harmful to humans unless you eat too many or have a health condition. Both vibrio types and the pseudomonas types are naturally found in the water that oysters are raised in, polluted or not.

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Data Table

	Number of Organism types	Number of colonies
Raw Oysters	5 types	100,000 +
Steamed for 1 min.	5 types	100,000 +
Steamed for 3 min.	1 type	1
Steamed for 5 min.	2 types	6

IV. SUMMARY AND CONCLUSION:

I conclude that cooking oysters substantially reduces the amount of bacteria present in oysters. A Person would have to cook oysters until they were shrivled and small if they wanted to destroy 99% of the bacteria present in oysters. The only way to be sure you are not eating bacteria from oysters that may compromise your health is to not eat oysters at all because there are certain northeastern bacteria that aren't killed by cooking. These are not a problem in Louisiana.

I reject my hypothesis. I did not find salmonella and e. coli bacteria in the oysters I tested. I did find bacteria that could make anyone sick not just those with compromised health as well as forms of bacteria that are only harmful if ingested in large quantities.

V. APPLICATION:

My project can be a source for people to turn to with questions about eating oysters in Louisiana. For instance, during the warmer summer months of the year, bacteria that are found naturally in the waters of oyster beds reproduce at a greater rate. Thus raw oysters eaten at these times will be more likely to contain high levels of bacteria which could harm healthy individuals if eaten in great quantity and individual with compromised health conditions. My research indicates that some individuals may want to stop eating raw oysters at this time of the year or thoroughly cook them.

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Commentary

This work provides evidence for the understanding of concepts such as the interdependence of organisms, especially the flow of energy, cooperation and competition, and environmental constraints. The idea that animals harbor bacteria, often naturally occurring and sometimes environmentally introduced, is evident for the interdependence of organisms. Many animals and bacteria live in cooperation with each other. Further, the use of agar as a growth medium and the identification of the need for sterile equipment provide evidence of an understanding of how bacteria grow.

This work provides evidence for connections with health—especially nutrition, disease, and toxic substances. The application section includes information on how the findings from this experiment would affect people who eat oysters. The connections between warmer summer months and higher bacteria levels are evidence for understanding toxic substances and their relationship to the environmental aspects of health. The understanding that most of these bacteria occur naturally and are not introduced by pollution and the caution regarding the risk to persons with "compromised health conditions" are evidence for the quality of work expected at the high school level.

The work is well within the range appropriate for high school. The first paragraph in the section that offers the analysis of data provides the best evidence of the quality of expected. Discussion of unexpected results and critique of one's own procedures are the kind of scientific thinking that is required. The procedures were well documented so that another student could replicate the investigation and verify the results. It was not stated whether the blender was sterilized between oyster samples nor whether the petri dishes were covered during incubation. However, the attention to detail evident in other portions of this work suggest not a procedural error but a simple omission in the write up. This is supported in the data.

The report is not explicit about how the different bacteria were identified. Identifying bacteria is sophisticated work for a high school student—assistance would have been appropriate (and should have been acknowledged). There is evidence of careful analysis when oyster size is identified as an important variable, through the amount of the sample in each condition is what should be controlled. The rejection of the hypothesis and the appropriate communication of the results of the investigation are also elements of scientific investigation.

HIGH SCHOOL SCIENCE ACTIVITY
"Density of Sand" *

Task

Students were asked to devise and carry out a method for determining the density of sand with air around the sand granules and the density of sand alone. Students were expected to work on the investigation in small groups and write up their reports individually. They were to submit a part of the investigation work and an entry slip on which they answered questions about the concept they investigated and the role they played in the investigation.

Show-Me Knowledge Standards Addressed

SC 1 properties and principles of matter and energy
SC 7 processes of scientific inquiry (such as formulating and testing hypotheses)

Show-Me Performance Standards Addressed

1.1 develop questions and ideas to initiate and refine research
1.2 conduct research to answer questions and evaluate information and ideas
1.3 design and conduct field and laboratory investigations to study nature and society
1.4 use technological tools and other resources to locate, select, and organize information
1.6 discover and evaluate patterns and relationships in information, ideas, and structures
1.7 evaluate the accuracy of information and the reliability of its sources
1.8 organize data, information and ideas in useful forms for analysis or presentation
2.1 plan and make written, oral, and visual presentations for a variety of purposes and audiences
2.2 review and revise communications to improve accuracy and clarity
2.4 present perceptions and ideas regarding works of the sciences
3.1 identify problems and define their scope and elements
3.2 develop and apply strategies based on ways others have prevented or solved problems
3.3 develop and apply strategies based on one's own experience in preventing or solving problems
3.4 evaluate the processes used in recognizing and solving problems
3.5 reason inductively from a set of specific facts and deductively from general premises
3.7 evaluate the extent to which a strategy addresses the problem
4.1 explain reasoning and identify information used to support decisions
4.4 recognize and practice honesty and integrity in academic work
4.5 develop, monitor, and revise plans of action to meet deadlines and accomplish goals
4.6 identify tasks that require a coordinated effort and work with others to complete those tasks

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Student Work

The Density of Sand

Purpose: To determine the density of a sample of sand with air around the sand granules and then the density of the sand alone.

Procedure:

Find mass of sand + cup	Record
Find mass of empty cup	Record
Subtract the mass of the empty cup from the mass of the sand + the cup. The result is the mass of the sand.	Record
Put sand in a graduated cylinder, note volume.	Record
Remove sand, put 20 mL water in graduated cylinder.	
Add sand to water, note volume of sand + water	Record
Subtract the volume of the water (20 mL) from the volume of the water + the sand. The result is the volume of the sand	Record

Data:

Mass of sand + cup (g)	Mass of cup (g)	Mass of sand (g)
17.30	1.85	15.45

Volume of water + sand(mL)	Volume of water(mL)	Volume of sand (w/o air)mL
26.0	20.0	6.0

Volume of with air: 10.4 mL

Density with air: $\frac{M}{V}$ $\frac{15.45\ g}{10.4\ mL}$ = 1.49 g/mL

Density without air: $\frac{M}{V}$ $\frac{15.45\ g}{6.0\ mL}$ = 2.6 g/mL

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Calculations and Analysis:

1. This lab was conducted using sand sample A. The mass of the sand was found by finding the mass of the sand in the cup, and then subtracting the mass of the cup. The mass of the sand was 15.45 g. The sand's volume with air, which was found by placing the sand in a graduated cylinder, was 10.4 mL. The sand's volume without air, which was found using the water displacement method, was 6.0 mL.

2. The density of the sand with air was found to be 1.49 g/ mL, and the density of the sand alone was 2.6 g/mL. The sand with the air had a lower density than the sand alone. The equation for density is mass divided by volume. For both density calculations, the mass of the sand was the same. However, the volume of the sand with the air was larger than the volume of the sand alone. This is because the grains of sand were separated by air, which made the volume larger than it would be if air was not present. Since the volume of the sand with air was larger, it had a lower density.

3. Our answers were compared with those of four other groups.

group #1:	density with air	1.4 g/ mL
	density without air	2.5 g/ mL
group #2	density with air	0.65 g/ mL
	density without air	1.02 g/ mL
group #3	density with air	3.0 g/ mL
	density without air	1.5 g/ mL
group #4	density with air	1.49 g/mL
	density without air	2.73 g/mL

4. Three out of the four groups we compared results with had answers very similar to our own. One group, #2, had results that were very different. Since density is an intensive property, the difference in sample sizes among the other groups should not have affected the results. Other groups also may have made errors in their measurements or in their procedures. By double-checking each group's measurements and calculations, it would be possible to determine which group had the most accurate results.

5. The procedure utilized in this lab would work well for small, irregular solids such as sand. Many objects, however, would be far too large to place in a graduated cylinder and use the water displacement method. In their instance larger containers could be used. It also would also be much easier to determine the density of regular solids using calculations of length, width, and other dimensions in conjunction mathematical formulas. This method was extremely successful in this example.

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GSE Self-reflection Sheet

GSE Self-reflection Sheet: Problem-solving Investigation

1. *Thoroughly* explain the scientific concept you are investigating in this entry. Give specific examples that show how this concept relates to your Problem-solving Investigation.

The purpose of this experiment was to determine the density of sand with air around it and the density of sand alone. The main concept in this lab is how the density of a substance is affected by its mass and volume, namely through the presence or the absence of air around the sand when determining the volume of the sample. This investigation introduces the idea that density is an intensive property, a concept that is reinforced by providing for different groups to use varied amounts of sand when performing these calculations. Density of a given substance remains constant regardless of the size of the sample used./

2. Describe, *in detail*, the part or parts of this investigation YOU personally designed.

This lab contained only a purpose, not a procedure. It was up to the students to design the entire method of determining the density of the sand both with and without air. I designed the plan to use the water displacement method for the volume of the sand without air, and to simply place the sand in a graduated cylinder in order to find it's volume with air. Please see the procedure section on page 1.

3. Describe how the scientific concept you investigated in this component is related to a real-world issue or personal experience (you may include issues that affect society or the environment).

The difference in density of objects around us is an integral part of our world. It would be rather difficult to float in the bathtub if water's density were as low as that of air, and just as difficult if water had a density similar to that of a solid. In the same way, it is crucial to our way of thinking and living that density be an intensive property. If the density of a given substance varied with the size of the sample measured, the results could be catastrophic. Imagine buying a 4"x4"x4" block of wood with which to build your home, and finding it to be of a much different consistency and stability than a 50"x50"x50" block of the same type of wood! Everyday we rely on the properties of density for our most basic functions and activities. This experiment simply made us aware of them.

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GSE Self-reflection Sheet: Problem-solving Investigation (cont'd)

4. Describe how working with others on this investigation helped to increase your understanding of science.

Although a hypothesis was not necessary in this investigation, my group worked together to develop a procedure in order to fulfill the purpose of this experiment. My partner and I brainstormed for a great length of time, debating the most efficient set-up and procedures to achieve the most accurate results. This involved many ideas being rejected as inefficient or inaccurate. For example, our first instinct was to simply spill the sand out onto the triple beam balance when determining its mass. Careful thought and discussion, however, caused us to realize that this would result in lost sand and therefore inaccurate results. We then devised a more accurate plan of weighing the sand within the cup, and then removing the sand from the cup and weighing the cup alone. We then subtracted the mass of the empty cup from the mass of the cup and the sand, and indirectly determined the mass of the sand. The entire procedure for this investigation was the result of a collaborative effort between my partner and I.

5. What did you conclude from the investigation? Was the conclusion the same as or different from what you expected? Describe how your observations and data support your conclusions.

From this investigation, we concluded that a sample of sand has a lower density when it is surrounded by air than when air is not present. My partner and I found sand surrounded by air to have a density of 1.49 g/mL, whereas sand that was not surrounded by air had a density of 2.6 g/mL. My partner and I found it interesting to discover that the presence or absence of air affects the density of a substance. This discovery was shown by the difference in our calculations of the density of the sand with air and without air. By comparing our results with those of other lab teams, we concluded that density is an intensive property. Although all of the teams used different amounts of sand in their calculations, their results were very similar, and in some cases identical to our own. This means that the density of a given substance does not change with the size of the sample measured.

In chemistry, as in most areas in life, collaborative efforts achieve the most accurate results in the most efficient manner. Working with a partner or a with a group enables individuals to master concepts and ideas that would be difficult or impossible for them to understand on their own. While brainstorming ideas for the procedure, my partner and I were able to "bounce" ideas off of one another and receive feedback and new ideas in return. In the same manner, if one partner had overlooked a small detail that might impede the obtaining of accurate results, the second partner was quick to see that potential problem and propose a solution. Through exchanging ideas, critique, questions, and information, my partner and I were able to understand the concepts presented in this investigation.

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Commentary

The work shows clear evidence for understanding the concept of density, e.g., "The equation for density is mass divided by volume." The inverse relationship that exists between density and volume is given in the statement, "Since the volume of the sand [with] air was larger, it had a lower density." This flexibility with a ratio concept of density would not be expected at the middle school level, where an understanding of the concept in concrete, physical terms is expected. The high school level understanding is further evident in the statement, "Since density is an intensive property, the difference in sample sizes among the other groups should not have affected the results." And the discussion of the real world applications of this understanding (see item #3 on the Self-reflection Sheet) shows that the student can generalize the situation from the immediate context.

The assignment required that the students develop an appropriate procedure. Water displacement is a technique routinely used to measure the volume of irregular solids. Generalizing from the standard use to the one in this experiment is a strong feature of both experimental design and measurement. Other aspects of scientific thinking are straightforward.

There is a clear attention to accuracy and precision throughout the work, e.g., "we devised a more accurate plan of weighing the sand within the cup...." The use of the graduated cylinder for the dry sand and then the use of the same equipment for the water displacement method shows attention to accuracy as well.

The comparison of one group to four others was further evidence of the check for accuracy. Three of the five groups had results which were similar. However, the explanation, "three out of four groups we compared results with had answers similar to our own," does not correspond to the data on the second page. It is likely that the data for Group #3 are reversed. This is supported when the further analysis explains that "other groups" might have made errors in measurement or procedures. The suggestion of all groups double checking their measurements and calculations is consistent with the quality of work required by the standards.

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Dear Users of *Missouri's Framework for Curriculum Development in*_____:
(subject)

We hope that this framework has been helpful to you in developing local curriculum aligned with The Show-Me Standards. Please take a few minutes to give the Department of Elementary and Secondary Education comments concerning your use of this document.

1. How did you use this framework? (Explain process.)

2. What parts of the framework were most helpful and why?

3. What suggestions do you have that would help make future versions of this document more useful?

4. If you have specific suggestions concerning certain pages, please indicate those page numbers and explain. Use the back of the page, if necessary.

Important Note:

By the end of the 1996-97 school year, we would also like to publicize Missouri students' quality work at elementary, middle and high school levels related to the Show-Me Standards. As you and other teachers in your district continue to develop performance-based activities/ assessments, please collect samples of quality student work. Samples submitted to DESE should follow the format in Appendix A of the framework.

Please return this sheet with your name and address to the Department of Elementary and Secondary Education, Curriculum Services, PO Box 480, Jefferson City, MO 65102. Call 573-751-2625 for more information concerning submissions of quality student work.

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